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(54) **ANALYSIS OF EATING HABITS**

ANALYSE VON ESSGEWOHNHEITEN

METHODE POUR ANALYSER DES HABITUDES ALIMENTAIRES

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Description**FIELD OF THE INVENTION**

- 5 **[0001]** The present invention relates generally to tracking eating habits, and specifically to invasive techniques and apparatus for detecting and analyzing the swallowing and digesting of food.

BACKGROUND OF THE INVENTION

- 10 **[0002]** Morbid obesity is a difficult to treat chronic condition defined by a body mass index ($BMI = \text{mass}/\text{height}^2$ [kg/m^2]) greater than 40. For obese persons, excessive weight is commonly associated with increased risk of cardiovascular disease, diabetes, degenerative arthritis, endocrine and pulmonary abnormalities, gallbladder disease and hypertension. Additionally, such persons are highly likely to experience psychological difficulties because of lifestyle restrictions such as reduced mobility and physical capacity, due to back pain, joint problems, and shortness of breath. In severe cases, this can contribute to absenteeism and unemployment. Moreover, impairment of body image can lead to significant psychological disturbances. Repeated failures of dieting and exercise to resolve the problem of obesity can result in feelings of despair and the development of clinical depression.
- 15 **[0003]** Bariatric surgery is often recommended for persons suffering from morbid obesity. Preferably, the invasive treatment is accompanied by changes in lifestyle, such as improved regulation of eating habits and an appropriate exercise regimen. Such lifestyle changes are dependent upon the self-discipline and cooperation of the patient.
- 20 **[0004]** A book entitled, Textbook of Gastroenterology, 3rd edition, edited by Yamada (Lippincott, Williams & Wilkins), has in Chapter 10 thereof a description of the physiology of gastric motility and gastric emptying.
- 25 **[0005]** An abstract entitled, "Gastric myoelectrical pacing as therapy for morbid obesity: Preliminary results," by Cigaina et al., retrieved on December 24, 2000 from the Web-site [http:// www.med-online.com / transneuronix / Product / abstract.htm](http://www.med-online.com/transneuronix/Product/abstract.htm), describes a method for applying monopolar and bipolar gastric stimulation to achieve weight loss.
- 30 **[0006]** An abstract entitled, "Implantable gastric stimulator (IGS) as therapy for morbid obesity: Equipment, surgical technique and stimulation parameters," by Cigaina et al., retrieved on December 24, 2000 from the Web-site [http:// www.medonline.com / transneuronix / Product / abstract.htm](http://www.medonline.com/transneuronix/Product/abstract.htm), describes techniques of electrical signal therapy designed to treat obesity.
- 35 **[0007]** US Patent 6,129,685 to Howard describes apparatus and methods for regulating appetite by electrical stimulation of the hypothalamus and by microinfusion of an appropriate quantity of a suitable drug to a distinct site or region within the hypothalamus.
- [0008]** US Patent 4,823,808 to Clegg et al. describes a method for treating obesity, including receiving a physiological measurement and generating audio or visual feedback for the patient to hear or see. The feedback is used for purposes of teaching behavior modification.
- 40 **[0009]** US Patent 5,868,141 to Elias describes an endoscopic stomach insert for reducing a patient's desire to eat.
- [0010]** US Patents 6,067,991 to Forsell, 5,601,604 to Vincent, 5,234,454 to Bangs, 4,133,315 to Berman et al., 4,416,267 to Garren et al., and US Patents 4,592,339, 5,449,368, 5,226,429 and 5,074,868 to Kuzmak describe mechanical instruments for implantation in or around the stomach of an obese patient.
- 45 **[0011]** US Patent 5,690,691 to Chen et al. describes a gastric pacemaker for treating obesity and other disorders. The pacemaker includes multiple electrodes which are placed at various positions on the gastrointestinal (GI) tract, and deliver phased electrical stimulation to pace peristaltic movement of material through the GI tract.
- [0012]** US Patent 5,423,872 to Cigaina describes apparatus for applying electrical pulses to the distal gastric antrum of a patient, so as to reduce the motility of the stomach and to thereby treat obesity or another disorder.
- 50 **[0013]** US Patents 5,188,104 and 5,263,480 to Wernicke et al. describe a method for stimulating the vagus nerve of a patient so as to alleviate an eating disorder.
- [0014]** US Patents 6,104,955, 6,091,992, and 5,836,994 to Bourgeois, 6,026,326 to Bardy, and 3,411,507 to Wingrove describe the application of electrical signals to the GI tract to treat various physiological disorders.
- [0015]** US Patent 5,979,449 to Steer describes an oral appliance for appetite suppression.
- 55 **[0016]** US Patent 4,975,682 to Kerr et al. describes apparatus for food intake regulation which is external to the body and which is based upon the voluntary cooperation of the subject in order to be effective.
- [0017]** US Patents 5,861,014 to Familoni, 5,716,385 to Mittal et al., and 5,995,872 to Bourgeois describe methods and apparatus for stimulation of tissue, particularly gastrointestinal tract tissue.
- [0018]** PCT Patent Publication WO 98/10830 to Ben-Haim et al., entitled, "Fencing of cardiac muscles," and US Patent Publication 6,415,178 in the national phase thereof, both of which are assigned to the assignee of the present patent application, describe various methods for controlling the behavior of muscle tissue, for example by blocking or altering the transmission of signals therethrough.
- [0019]** PCT Patent Publication WO 99/03533 to Ben-Haim et al., entitled, "Smooth muscle controller," and US Patent

Publication 6,571,127 in the national phase thereof, both of which are assigned to the assignee of the present patent application, describe apparatus and methods for applying signals to smooth muscle so as to modify the behavior thereof. In particular, apparatus for controlling the stomach is described in which a controller applies an electrical field to electrodes on the stomach wall so as to modify the reaction of muscle tissue therein to an activation signal, while not generating a propagating action potential in the tissue. In the context of the present patent application and in the claims, the use of such a non-excitatory signal to modify the response of one or more cells to electrical activation thereof, without inducing action potentials in the cells, is referred to as Excitable-Tissue Control (ETC). Use of an ETC signal is described in the PCT Patent Publication with respect to treating obesity, by applying the ETC signal to the stomach so as to delay or prevent emptying of the stomach. In addition, a method is described for increasing the motility of the gastrointestinal tract, by applying an ETC signal to a portion of the tract in order to increase the contraction force generated in the portion.

[0020] US Patent Publication 5,292,344 discloses a gastrointestinal pacemaker stimulatory system that is able to sense and variably pace motor activity of the intestinal tract.

[0021] US patent publication 5,188,104 discloses a system and a method of treating patients with compulsive eating disorders, wherein sensors placed in the esophagus and in the stomach are used to determine the amount of food ingested. Vagal stimulation is then delivered to provide a sensation of satiety.

SUMMARY OF THE INVENTION

[0022] It is an object of the present invention to provide an apparatus and a method for detecting and tracking the swallowing of solids and liquids.

[0023] It is a further object of the present invention to provide an apparatus and a method for detecting, tracking, quantifying and determining the qualitative character of ingested liquids and solids.

[0024] It is still a further object of the present invention to provide improved an apparatus and a method for treating obesity.

[0025] It is yet a further object of the present invention to provide an apparatus and a method that enable the implementation of changes in food ingestion habits in a predictable and controlled manner.

[0026] It is an additional object of the present invention to provide an apparatus for regulating food ingestion.

[0027] These objects are achieved by the invention as defined in the appended claims.

[0028] In preferred embodiments of the present invention, apparatus for detecting, tracking, quantifying and determining the qualitative character of ingested liquids and solids comprises a sensor coupled to a patient's gastrointestinal tract. Preferably, the sensor generates a signal indicative of the swallowing of food. An analysis module preferably determines a quality of the food, for example, whether it is predominantly solid or liquid, and stores this information in an electronic memory. "Food," as used in the context of the present patent application and in the claims, is to be understood as including both solid and liquid food. "Swallowing," as used in the context of the present patent application and in the claims, is to be understood as being indicative of the onset of eating.

[0029] In some preferred embodiments of the present invention, swallowing is detected by tracking the electrical activity in muscle tissue in the fundic region of the stomach. Typically, the commencement of enhanced electrical activity is also detected in muscle tissue in the antral region of the stomach. Measurement of the time delay between swallowing and the commencement of electrical activity in the antrum is preferably used to differentiate between solid and liquid matter, which are generally passed at different rates through the stomach.

[0030] Alternatively or additionally, swallowing is detected by at least one sensor placed at a site on the gastrointestinal tract other than the fundic region of the stomach, and the sensor generates a signal indicative of swallowing. Appropriate sites include, but are not limited to, a site on the esophagus, a site on the stomach, and a site on the throat. Whenever detection of swallowing is described in the present patent application with respect to fundic activity, it is to be understood as being by way of example, and not as excluding detection by a sensor located elsewhere on the gastrointestinal tract.

[0031] Preferably, measurement of the intensity and/or duration of the electrical activity in the antral region is correlated with aspects of fundic electrical activity denoting swallowing, as described hereinbelow, such that ingested matter of differing chemical and nutritional content can be distinguished. Further preferably, the amount of food accumulated in the fundus or antrum is estimated by measuring a level of electrical activity at various sites in the stomach.

[0032] Typically, electrical activity response criteria of the stomach of an individual patient are determined and calibrated by measuring the response of the patient's stomach to various types of solid and liquid food. To ensure appropriate compliance, calibration is preferably performed under the supervision of a healthcare worker. For illustration, a table such as the following may be established for a particular patient. Except with respect to the example of sugarless chewing gum, these illustrative values are shown with respect to a constant volume of food or liquid ingested (e.g., 100 ml or steak, water, or tomato juice).

TABLE I

Substance	Fundic activity level	Antral activity level	Time delay until onset of antral activity
Sugarless chewing gum	1	1	-
Non-caloric liquid - Water	2	1	-
Caloric liquid - Tomato juice	2	2	<1 Minute
Caloric liquid - Milk	2	2	<1 Minute
Solid - Apple	2	2	Minutes
Solid - Meat	2	3	Minutes

[0033] In this illustration, the measured data are preferably analyzed to determine signal characteristics which correspond to the indicated fundic and antral electrical activity levels. For example, calibration of fundic activity during the chewing of sugarless gum typically yields a low level indication of swallowing, while calibration during the swallowing of liquids and solids yields a greater fundic response. Similarly, there is typically no significant antral response to the patient drinking water, while calibration during the digestion of liquids and solids having higher caloric content yields a greater antral response. Measurements are preferably made of the delay time between swallowing and the commencement of antral activity, because consumption of liquids is typically characterized by a rapid transition from the fundus to the antrum, while solids typically stay in the fundus for at least about 10 minutes prior to being passed to the antrum. Preferably, a large variety of liquids and solids are used to establish a profile of electrical response characteristics for each patient.

[0034] For some applications, various supplemental sensors are also applied to the gastrointestinal tract or elsewhere on or in the patient's body. These supplemental sensors, which may comprise pH sensors, blood sugar sensors, ultrasound transducers or mechanical sensors, typically convey signals to a control unit of the apparatus indicative of a characteristic of solids or liquids ingested by the patient. For example, an ultrasound transducer may be coupled to indicate whether ingesta are solid or liquid, and a pH sensor may indicate that an acidic drink such as tomato juice was consumed rather than a more basic liquid such as milk.

[0035] In a preferred embodiment, the collected data are stored and intermittently uploaded to an external computer, preferably by a wireless communications link, for review by the patient's physician, to enable monitoring of the patient's adherence to a dietary regimen.

[0036] For some applications, a specific schedule of allowed food ingestion is pre-programmed by the physician into the memory, and a processor is continuously operative to detect whether food consumption is taking place in accordance with the programmed schedule. For some patients, the schedule may be less strict with respect to drinking certain types of liquids, and more strict with respect to eating certain types of solid food. When an exception from the schedule is detected, the processor preferably actuates a signal generator to convey an ingestion-control signal to the patient, in order to encourage the patient to adhere to the schedule. Preferably, but not necessarily, apparatus and methods described in US Provisional Patent Application 60/259,925, entitled, "Regulation of eating habits," filed January 5, 2001, and in PCT patent application WO 02/053093, entitled, "Regulation of eating habits," filed in January, 2002, both of which are assigned to the assignee of the present patent application, are utilized in the administration of the ingestion-control signal. Alternatively or additionally, the signal generator generates a visual, audio, or other cue or causes another reasonable discomfort to encourage the patient to adhere to the schedule.

[0037] For embodiments in which this form of dietary monitoring is supplemented by dietary regulation, the apparatus preferably compares the indications of actual food and drink consumption with the pre-programmed schedule. In the event of a sufficient level of patient non-compliance, the ingestion-control signal is preferably delivered to the patient's stomach via a set of electrodes placed in a vicinity thereof, so as to induce a sensation of discomfort or minor nausea. For example, an unpleasant sensation such as nausea may be induced by altering the natural electrical activity of the stomach, thereby inducing gastric dysrhythmia, or, alternatively, discomfort may be induced by pacing the rectus abdominus muscle.

[0038] Alternatively or additionally, the signal is applied to another site on or in the patient's body. For example, the ingestion-control signal may be applied mechanically or electrically in a vicinity of the cochlear nerve, so as to induce vertigo. Alternatively, the signal is applied so as to generate a brief pain sensation anywhere on the patient's body, which only recurs if the patient continues to eat. Further alternatively, the signal is applied to the esophagus or to the lower esophageal sphincter, so as to cause contraction of muscle tissue therein, thereby making any further eating difficult or very uncomfortable.

[0039] Alternatively or additionally, the ingestion-control signal is configured so as to induce a feeling of satiation, preferably but not necessarily in accordance with methods described in US Patent Application 2002/161414, entitled,

"Acute and chronic electrical signal therapy for obesity," filed on December 11, 2000, which is assigned to the assignee of the present patent application. For example, methods described in that application for engendering a feeling of satiation may be applied in conjunction with embodiments of the present invention, such that muscles in the vicinity of stretch receptors in the stomach are caused to contract, thereby resulting in decreased hunger sensations. Alternatively or additionally, the feeling of satiation is induced by applying electrical signals which enhance the mobility of chyme from the fundus to the antrum of the stomach, where stretch-receptor signals are generally generated to a greater extent for a given quantity of food than in the fundus.

[0040] In a preferred embodiment, when an exception from the schedule of allowed food ingestion is detected, the processor preferably conveys the exception to an external operator control unit, which in turn wirelessly communicates the exception in real time to a remote computer system. The remote computer system can be configured to analyze the exception based on predetermined rules and, if necessary, perform an appropriate action, such as notification of a healthcare worker, care provider, or family member of the patient, in order to encourage the patient to adhere to the schedule.

[0041] Preferably, the schedule of allowed food ingestion can be modified after implantation of the apparatus, typically by means of a wireless communications link. In this manner, the schedule can be adjusted in response to changes in the patient's eating habits and experience with the apparatus.

[0042] There is therefore provided, in accordance with the present invention, gastric apparatus, including:

a gastrointestinal sensor, adapted to be coupled to a gastrointestinal site of a subject and to generate a gastrointestinal sensor signal responsive to a property of the gastrointestinal site;
 a set of one or more antral sensors, adapted to be coupled to an antral site of an antrum of the stomach and to generate an antral sensor signal responsive to a property of the antrum; and
 a control unit, adapted to receive and analyze the gastrointestinal and antral sensor signals, and to determine, responsive thereto, a characteristic of a food ingested by the subject.

[0043] Preferably, the control unit is adapted to be implanted in the subject.

[0044] For some applications, the apparatus includes an operator unit, which is adapted to be disposed external to the subject and to transmit a control signal to the control unit.

[0045] In a preferred embodiment, the gastrointestinal sensor is adapted to generate a swallowing sensor signal responsive to swallowing by the subject. Typically, the gastrointestinal sensor is adapted to be placed at an esophageal site of the subject, a site of the stomach of the subject, and/or a site of a throat of the subject.

[0046] The gastrointestinal sensor includes a set of one or more fundic sensors, adapted to be coupled to a fundic site of a fundus of the stomach of the subject and to generate a fundic sensor signal responsive to a property of the fundus, and the control unit is adapted to receive and analyze the fundic and antral sensor signals, and to determine, responsive thereto, the characteristic of the ingested food. In a preferred embodiment, the fundic sensor set includes one or more strain gauges. Alternatively or additionally, the antral sensor set includes one or more strain gauges.

[0047] Typically, the fundic sensor set includes a set of fundic electrodes, adapted to generate a fundic electrode signal responsive to a property of the fundus, the antral sensor set includes a set of antral electrodes, adapted to generate an antral electrode signal responsive to a property of the antrum, and the control unit is adapted to receive and analyze the fundic and antral electrode signals, and to determine, responsive thereto, the characteristic of the ingested food. For example, the control unit may be adapted to determine, responsive to an analysis of at least one of the electrode signals, an amount of the ingested food accumulated in a region of the stomach. Alternatively or additionally, the control unit is adapted to count, responsive to an analysis of at least one of the electrode signals, a number of meals ingested by the subject during a period of time.

[0048] The antral electrode set typically includes two antral electrodes, adapted to be coupled to two sites of the antrum, and the control unit is adapted to identify a measure of electrical impedance between the two sites of the antrum. In this case, the control unit is preferably adapted to determine the characteristic of the ingested food, responsive to a change in the measure of electrical impedance. For some applications, the fundic electrode set includes two fundic electrodes, adapted to be coupled to two sites of the fundus, and the control unit is adapted to identify a measure of electrical impedance between the two sites of the fundus. For example, the control unit may be adapted to determine the characteristic of the ingested food, responsive to a change in the measure of electrical impedance. Alternatively or additionally, the control unit is adapted to identify an increased measure of electrical impedance relative to a baseline value as indicative of eating. Further alternatively or additionally, the control unit is adapted to identify a substantial return towards a baseline value of the measure of electrical impedance as indicative of a termination of eating.

[0049] For some applications, the control unit is adapted to identify an increase in the measure of electrical impedance as indicative of an onset of eating. For example, the control unit may be adapted to detect the onset of eating, responsive to the increase in the measure of electrical impedance being greater than 5 ohms per centimeter of distance between the two sites of the fundus.

[0050] In a preferred embodiment, the control unit is adapted to perform a calibration including measurement of a response of the fundic and antral electrode signals to ingestion by the subject of one or more test foods. For example, the one or more foods may include one or more solid foods, and the control unit may be adapted to perform the calibration responsive to ingestion of the one or more solid foods. Alternatively or additionally, the one or more foods includes one or more liquid foods, and the control unit is adapted to perform the calibration responsive to ingestion of the one or more liquid foods. Further alternatively or additionally, the one or more foods includes one or more solid foods and one or more liquid foods, and herein the control unit is adapted to perform the calibration responsive to ingestion of the one or more solid foods and the one or more liquid foods.

[0051] In a preferred embodiment, the antral electrode set is adapted to generate the antral electrode signal responsive to an electrical potential change generated responsive to a contraction of a muscle of the antrum. In this case, the control unit is preferably adapted to determine, responsive to an amplitude of the antral electrode signal, the characteristic of the ingested food. Alternatively or additionally, the control unit is adapted to determine, responsive to a frequency of the antral electrode signal, the characteristic of the ingested food. Further alternatively or additionally, the control unit is adapted to determine, responsive to a spike energy per antral cycle of electrical activity, the characteristic of the ingested food. Still further alternatively or additionally, the control unit is adapted to determine, responsive to a duration of the antral electrode signal, the characteristic of the ingested food.

[0052] In a preferred embodiment, the control unit is adapted to determine, responsive to a change in a rate of antral electrode signal events, the characteristic of the ingested food. The control unit may alternatively or additionally be adapted to identify an increase in an amplitude of the antral electrode signal as indicative of an onset of a cephalic phase occurring in the subject. For some applications, the control unit is adapted to identify an increase in an amplitude of the antral electrode signal as indicative of an onset of antral digestion. Alternatively or additionally, the control unit is adapted to identify a reduction in a rate of antral electrode signal events as indicative of an onset of antral digestion.

[0053] For some applications, the control unit is adapted to identify an increased amplitude of the antral electrode signal relative to a baseline value as indicative of antral digestion. Alternatively or additionally, the control unit is adapted to identify a reduced rate of antral electrode signal events relative to a baseline value as indicative of antral digestion. Further alternatively or additionally, the control unit is adapted to identify a substantial return towards a baseline value of an amplitude of the antral electrode signal as indicative of a termination of antral digestion. Still further alternatively or additionally, the control unit is adapted to identify a substantial return towards a baseline value of a rate of antral electrode signal events as indicative of a termination of antral digestion.

[0054] The control unit is preferably adapted to determine the characteristic of the ingested food, responsive to a time delay between an onset of eating and an onset of a decreased rate of electrical events in the antrum. For some applications, the control unit is adapted to determine the characteristic of the ingested food, responsive to the time delay and responsive to a threshold time delay. Alternatively or additionally, the control unit is adapted to determine, responsive to the time delay, an extent to which the ingested food includes solid food matter. In this case, the control unit is preferably adapted to determine that the ingested food includes solid food matter, responsive to the time delay being more than about one minute. For some applications, the control unit is adapted to determine that the ingested food includes predominantly solid food matter, responsive to the time delay being more than about 5 minutes.

[0055] In a preferred embodiment, the control unit is adapted to determine, responsive to the time delay, an extent to which the ingested food includes liquid food matter. For example, the control unit may be adapted to determine that the ingested food includes liquid food matter, responsive to the time delay being less than about 5 minutes. Alternatively or additionally, the control unit is adapted to determine that the ingested food includes predominantly liquid food matter, responsive to the time delay being less than about one minute.

[0056] For some applications, the control unit is adapted to determine the characteristic of the ingested food, responsive to a time delay between an onset of eating and an onset of increased electrical activity in the antrum. In this case, the control unit is preferably adapted to determine the characteristic of the ingested food, responsive to the time delay and responsive to a threshold time delay. Further preferably, the control unit is adapted to determine, responsive to the time delay, an extent to which the ingested food includes solid food matter. For example, the control unit may be adapted to determine that the ingested food includes solid food matter, responsive to the time delay being more than about one minute. Alternatively or additionally, the control unit may be adapted to determine that the ingested food includes predominantly solid food matter, responsive to the time delay being more than about 5 minutes. In a preferred embodiment, the control unit is adapted to determine, responsive to the time delay, an extent to which the ingested food includes liquid food matter. For example, the control unit may be adapted to determine that the ingested food includes liquid food matter, responsive to the time delay being less than about 5 minutes. Alternatively or additionally, the control unit is adapted to determine that the ingested food includes predominantly liquid food matter, responsive to the time delay being less than about one minute.

[0057] Preferably, the fundic electrode set is adapted to generate the fundic electrode signal responsive to an electrical potential change generated responsive to a contraction of a muscle of the fundus. For example, the control unit may be adapted to determine the characteristic of the ingested food responsive to an amplitude of the fundic electrode signal,

a frequency of the fundic electrode signal, a duration of the fundic electrode signal, and/or a change in a rate of fundic electrode signal events of the fundic electrode signal.

[0058] In a preferred embodiment, the control unit is adapted to identify an increased amplitude of the fundic electrode signal relative to a baseline value as indicative of eating. Alternatively or additionally, the control unit is adapted to identify an increased frequency of the fundic electrode signal relative to a baseline value as indicative of eating. Further alternatively or additionally, the control unit is adapted to identify a substantial return towards a baseline value of an amplitude of the fundic electrode signal as indicative of a termination of eating. Still further alternatively or additionally, the control unit is adapted to identify a substantial return towards a baseline value of a frequency of the fundic electrode signal as indicative of a termination of eating. For some applications, the control unit is adapted to identify an increase in an amplitude of the fundic electrode signal as indicative of an onset of eating. For example, the control unit may be adapted to detect the onset of eating responsive to the increase in the amplitude of the fundic electrode signal being greater than about 20 percent.

[0059] In a preferred embodiment, the control unit is adapted to identify an increase in a frequency of the fundic electrode signal as indicative of an onset of eating. For example, the control unit may be adapted to detect the onset of eating, responsive to the increase in the frequency being greater than about 10 percent.

[0060] In a preferred embodiment, the control unit includes a memory, adapted to store a result of the analysis performed by the control unit. Preferably, the memory is adapted to upload the stored result to an external computer, e.g., by using a wireless communications link.

[0061] In a preferred embodiment, the apparatus includes a supplemental sensor adapted to be placed at a site of the subject and to convey a supplemental sensor signal to the control unit. The control unit is preferably adapted to receive and analyze the supplemental sensor signal, and to determine, responsive thereto, the characteristic of the ingested food. Alternatively or additionally, the control unit is adapted to receive and analyze the supplemental sensor signal, and to determine, responsive thereto, an onset of eating by the subject. Further alternatively or additionally, the control unit is adapted to receive and analyze the supplemental sensor signal, and to determine, responsive thereto, eating by the subject. Still further alternatively or additionally, the control unit is adapted to receive and analyze the supplemental sensor signal, and to determine, responsive thereto, a termination of eating by the subject. Preferably, the supplemental sensor includes an electrode, a pH sensor, a blood sugar sensor, an ultrasound transducer, and/or a mechanical sensor, in a preferred embodiment, the supplemental sensor is adapted to be placed at a gastrointestinal site of the subject, an esophageal site of the subject, a site of the stomach of the subject, and/or a site of a throat of the subject.

[0062] For some applications, the control unit includes a memory, adapted to store a schedule of allowed food ingestion, wherein the apparatus includes an operator unit, which is adapted to be disposed external to the subject, and wherein the operator unit is adapted to generate an external cue when the analysis performed by the control unit is indicative of the subject not eating in accordance with the ingestion schedule. For example, the external cue may include a visual cue, and the operator unit is adapted to generate the visual cue. Alternatively or additionally, the external cue includes an audio cue, and the operator unit is adapted to generate the audio cue. For some applications, the operator unit includes a user override, adapted to be used by the subject and adapted to disable the cue. Alternatively or additionally, the operator unit is adapted to modify the schedule stored in the memory. For example, the operator unit may be adapted to modify the schedule responsive to information obtained by the operator unit, e.g., via a wireless communications link.

[0063] In a preferred embodiment, the apparatus includes a set of one or more current-application electrodes, adapted to be coupled to a tissue of the subject, and wherein the control unit is adapted to drive a current, responsive to the analysis, through the set of current-application electrodes into the tissue. For example, the current-application electrode set may be adapted to be placed at an aural site of the subject, at an esophageal site of the subject, and/or at a site of the stomach of the subject. For some applications, the control unit is adapted to drive the current into the tissue responsive to the characteristic of the ingested food. In a preferred embodiment, the control unit is adapted to apply a pacing signal to a rectus abdominus muscle of the subject. For some applications, the control unit is adapted to drive the current into the tissue responsive to a time of the subject eating.

[0064] In a preferred embodiment, the control unit is adapted to configure the current such that driving the current induces gastric dysrhythmia. Alternatively or additionally, the control unit is adapted to configure the current such that driving the current disrupts coupling of gastric mechanical activity and gastric electrical activity of the subject. Further alternatively or additionally, the control unit is adapted to configure the current such that driving the current induces a sensation of discomfort in the subject. Still further alternatively or additionally, the control unit is adapted to configure the current such that driving the current induces a sensation of nausea in the subject. Yet further alternatively or additionally, the control unit is adapted to configure the current such that driving the current induces a sensation of vertigo in the subject.

[0065] In a preferred embodiment, the control unit is adapted to drive the current-application electrode set to apply an Excitable-Tissue Control (ETC) signal to the tissue. For example, the control unit may be adapted to drive the current-application electrode set to apply a stimulatory pulse at a site of application of the ETC signal. Alternatively or additionally,

the control unit is adapted to drive the current-application electrode set to apply a stimulatory pulse to tissue at a site other than a site of application of the ETC signal. Still further alternatively or additionally, the control unit is adapted to drive the current-application electrode set to apply the ETC signal in order to increase an aspect of contraction of the tissue. For some applications, the control unit is adapted to drive the current-application electrode set to apply the ETC signal in order to cause tissue contraction in a first portion of the stomach of the subject, and stretching of a stretch receptor of the stomach in a second portion of the stomach. Alternatively or additionally, the control unit is adapted to drive the current-application electrode set to apply the ETC signal in order to increase a contraction strength of tissue in a vicinity of a stretch receptor of the stomach of the subject, so as to increase a sensation of satiation of the subject. Further alternatively or additionally, the control unit is adapted to drive the current-application electrode set to apply the ETC signal to the tissue so as to enhance movement of chyme from a fundus to the antrum of the stomach of the subject.

[0066] In a preferred embodiment, the control unit includes a memory, adapted to store a schedule of allowed food ingestion, and wherein the control unit is adapted to withhold driving the current when the analysis performed by the control unit is indicative of the subject eating in accordance with the ingestion schedule. Preferably, the ingestion schedule includes types of foods and associated amounts permitted during a time period, and the control unit is adapted to withhold driving the current when the analysis is indicative of the subject eating in accordance with the ingestion schedule. Alternatively or additionally, the ingestion schedule includes a number of meals permitted during a time period, and the control is adapted to withhold driving the current when the analysis is indicative of the subject eating in accordance with the ingestion schedule. Further alternatively or additionally, the ingestion schedule includes an amount of food permitted at a certain meal, and the control is adapted to withhold driving the current when the analysis is indicative of the subject eating in accordance with the ingestion schedule.

[0067] Preferably, the memory is adapted to download a new schedule from an external computer. For some applications, the apparatus includes an operator unit, which is adapted to be disposed external to the subject and to transmit a control signal to the control unit. Further preferably, the operator unit includes a user override, adapted to be used by the subject and adapted to withhold driving the current.

[0068] There is further provided, in accordance with the present invention, a method for analyzing gastric function of a stomach of a subject, including:

- sensing a property of a gastrointestinal tract of the stomach;
- sensing a property of an antrum of the stomach;
- analyzing the property of the gastrointestinal tract and the property of the antrum; and
- determining, responsive to the analysis, a characteristic of a food ingested by the subject.

[0069] The gastric apparatus of the present invention is defined in appended claim 1. Further optional features thereof are defined in sub claims 2-36.

[0070] The method according to the invention is defined in appended claim 37. Further optional features thereof are defined in sub claims 38-43.

[0071] Disclosed herein are methods of implanting or inserting an apparatus or parts thereof into the patient, as well as delivering electric stimulation to the patient. These methods, however, do not form part of the invention.

[0072] The present invention will be more fully understood from the following detailed description of the preferred embodiments thereof, taken together with the drawings, in which:

BRIEF DESCRIPTION OF THE DRAWINGS

[0073]

Fig. 1 is a schematic illustration of apparatus for treating obesity, in accordance with a preferred embodiment of the present invention;

Fig. 2 is a schematic block diagram showing a control unit of the apparatus of Fig. 1, in accordance with a preferred embodiment of the present invention;

Fig. 3 is a schematic diagram showing experimental apparatus used to measure electrical responses to eating in the stomach of a normal rabbit, in accordance with a preferred embodiment of the present invention;

Fig. 4 is a graph showing electrical activity in the fundus of a normal rabbit before and during eating, and results of analysis thereof, in accordance with a preferred embodiment of the present invention;

Figs. 5A is a graph showing electrical activity in the fundus of a normal rabbit during and following eating, and results

of analysis thereof, in accordance with a preferred embodiment of the present invention;

Fig. 5B is a graph showing details of electrical and mechanical activity recorded during the taking of the data shown in Fig. 5A;

Fig. 6 is a graph showing detail of electrical fundic activity, measured in accordance with a preferred embodiment of the present invention;

Fig. 7 is a graph showing the rate of electrical events in the antrum of a normal dog before and during eating, and results of analysis thereof, in accordance with a preferred embodiment of the present invention;

Fig. 8 is a graph showing the rate of electrical events in the antrum of a normal dog before, during, and after eating, and results of analysis thereof, in accordance with a preferred embodiment of the present invention;

Fig. 9 is a graph showing electrical and mechanical activity and the rate of electrical events in the antrum of a normal dog before, during, and after eating, and results of analysis thereof, in accordance with a preferred embodiment of the present invention; and

Fig. 10 is a graph showing fundic electrical activity in a normal dog during several periods of eating and non-eating, and results of analysis thereof, in accordance with a preferred embodiment of the present invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0074] Fig. 1 is a schematic illustration of diet evaluation apparatus 18, which detects when a patient 10 swallows, and detects the type and amount of matter ingested, in accordance with a preferred embodiment of the present invention. Preferably, but not necessarily, apparatus 18 additionally determines, responsive to the detection, whether to apply electrical energy to modify the activity of tissue of patient 10. Apparatus 18 typically comprises mechanical sensors 70, supplemental sensors 72, local sense electrodes 74, operator controls 71, and one or more current-application electrodes 100.

[0075] Electrodes 74 and 100 are typically coupled to the serosal layer of a stomach 20 and/or inserted into the muscular layer of the stomach in the fundic and antral regions. Alternatively or additionally, the electrodes are coupled elsewhere on the stomach, gastrointestinal tract, or to other suitable locations in or on the patient's body. The number of electrodes and sensors, as well as the positions thereof, are shown in Fig. 1 by way of example, and other sites on stomach 20 or in or on the patient's body are appropriate for electrode and sensor placement in other applications of the present invention. Different types of electrodes known in the art are typically selected based on the specific condition of the patient's disorder, and may comprise stitch, coil, screw, patch, basket, needle and/or wire electrodes, or substantially any other electrode known in the art of electrical stimulation or sensing in tissue.

[0076] Preferably, apparatus 18 is implanted in patient 10 in a manner generally similar to that used to implant gastric pacemakers or other apparatus for stimulating or sensing in the gastrointestinal tract that are known in the art. As appropriate, techniques described in one or more of the references cited in the Background section of the present patent application may be adapted for use with these embodiments of the present invention. Other methods and apparatus useful in carrying out some embodiments of the present invention are described in the above-cited US Provisional Patent Application 60/259,925, entitled, "Regulation of eating habits," filed on January 5, 2001, and in the above-cited PCT patent application WO 02/053093 and in the above-cited US Patent Application 2002/161414, entitled, "Acute and chronic electrical signal therapy for obesity," filed on December 11, 2000, which are assigned to the assignee of the present patent application.

[0077] Fig. 2 is a schematic block diagram illustrating details of operation of a control unit 90 of apparatus 18, in accordance with a preferred embodiment of the present invention. Preferably, control unit 90 is implanted in patient 10, and receives signals from mechanical sensors 70, supplemental sensors 72, and local sense electrodes 74, all of which are typically implanted on the gastrointestinal tract of the patient or elsewhere on or in the body of the patient. These sensors and electrodes are preferably adapted to provide an "ingestion activity analysis" block 80 of the control unit with information about food ingestion and/or the present state of the stomach.

[0078] Preferably, using techniques described hereinbelow, analysis block 80 determines each time that the patient swallows, and also the character and amount of the ingested matter. For example, local sense electrodes 74 coupled to the fundus of the stomach may send signals indicative of fundic electrical activity to analysis block 80, and analysis block 80 identifies aspects of these signals which are characteristic of swallowing of food by the patient. Additionally, mechanical sensors 70 and local sensor electrodes 74 coupled to the corpus and antral regions of the stomach preferably send signals which analysis block 80 identifies as indicative of the onset, duration, and/or intensity of the digestive

process in those regions. Preferably, these data are utilized by analysis block 80 to determine a quality of the ingested matter, for example, whether it is predominantly solid or liquid.

[0079] In a preferred embodiment, analysis block 80 determines the time delay between swallowing (as measured, preferably, by local sense electrodes 74 on the fundus) and the commencement of electrical and mechanical activity in the antrum. This delay is typically used to differentiate between the ingestion of solid and liquid matter, because solids are generally held in the fundus for at least about 10 minutes before being passed to the antrum, while liquids are generally passed to the antrum essentially immediately.

[0080] Alternatively or additionally, the amount of food accumulated in the various regions of stomach 20 is estimated by measuring a level of electrical or mechanical activity in a vicinity of those regions. Further alternatively or additionally, analysis block 80 processes data from supplemental sensors 72 indicative of the blood sugar level of the patient, to enable an evaluation of whether and of what type of food has been ingested.

[0081] In order to improve the accuracy of the analyses described hereinabove, analysis block 80 is preferably calibrated by measuring the appropriate electrical response criteria of stomach 20 of patient 10 to various types of solid and liquid food. To ensure appropriate compliance, calibration is preferably performed under the supervision of a healthcare worker.

[0082] For some applications, analysis block 80 stores the results of its analysis in a memory block 88 of control unit 90, and these results are later uploaded to an external computer, preferably by a wireless communications link, for review by the patient's physician. Alternatively or additionally, analysis block 80 conveys results of its analysis of the inputs from mechanical sensors 70, supplemental sensors 72, and local sense electrodes 74, to a "parameter search and tuning" block 84 of control unit 90. Block 84 preferably evaluates the analysis performed by analysis block 80 with respect to a pre-programmed or variable ingestion schedule stored in memory block 88, so as to determine whether the patient is eating in compliance with the schedule. Preferably, the schedule can be modified after implantation of control unit 90, by communication from operator controls 71 using methods described hereinbelow. If it is determined that the patient's eating is not in compliance with the schedule (e.g., the patient has eaten too much at one meal, or has eaten too many meals in a day, or has had too much of a certain type of food or drink), then block 84 preferably actuates a signal generator block 86 to generate electrical signals that are applied by current-application electrodes 100 to tissue of patient 10. Block 86 preferably comprises amplifiers, isolation units, and other standard circuitry known in the art of electrical signal generation.

[0083] The signals generated by block 86 are preferably configured so as to induce a response appropriate for controlling the patient's eating habits. For example, block 86 may drive current-application electrodes 100 to apply signals to the stomach that induce gastric dysrhythmia and the resultant feeling of discomfort or nausea. Alternatively or additionally, the signals are applied to an aural site of patient 10 (e.g., in a vicinity of the cochlear nerve or the tympanic membrane), and are configured to induce vertigo, or another unpleasant balance-related sensation. Alternatively or additionally, block 86 generates a visual, audio, or other cue to encourage the patient to adhere to the schedule.

[0084] For some applications, control unit 90 drives electrodes 100 to apply a modulation signal to muscle in one area of stomach 20, so as to induce a contraction of the stimulated muscle that, in turn, induces satiety when food in an adjacent area of the stomach causes additional stretching of stretch-receptors therein. This signal may be applied in addition to or instead of the signals described hereinabove that produce gastric or other discomfort. The form of contraction-mediated stretching utilized in these applications simulates the normal appetite-reduction action of the stomach's stretch-receptors, without the patient having eaten the quantities of food which would normally be required to trigger this appetite-reduction response. In a preferred application, current-application electrodes 100 are placed around the body of the stomach and are driven to induce a generally steady-state contraction of the corpus, which simulates electrically the squeezing of the corpus produced mechanically by implanted gastric bands known in the art.

[0085] Preferably, the signals applied by current-application electrodes 100 include, as appropriate, an Excitable-Tissue Control (ETC) signal and/or an excitatory signal that induces contraction of muscles of the stomach. Aspects of ETC signal application are typically performed in accordance with techniques described in the above-referenced PCT Publications WO 99/03533 and WO 97/25098 and their corresponding US Patent Publications 6,571,127 and 6,317,631, *mutatis mutandis*.

[0086] Preferably, evaluation apparatus 18 includes remote operator controls 71, external to the patient's body. This remote unit is typically configured to enable the patient or his physician to change parameters of the ingestion schedule stored in memory block 88. For example, if the patient has lost weight, the physician may change the ingestion schedule to allow a single mid-afternoon snack. Alternatively or additionally, operator controls 71 comprise an override button, so that the patient may eat outside of the designated meal times, or consume a particular food or drink not in accordance with the schedule, if the need arises. Operator controls 71 preferably communicate with control unit 90 using standard methods known in the art, such as magnetic induction or radio frequency signals.

[0087] Fig. 3 is a schematic diagram showing experimental apparatus 60 used to measure electrical responses to eating in the stomach 64 of a normal rabbit, in accordance with a preferred embodiment of the present invention. Bipolar sense electrodes 62 were coupled to the fundus of stomach 64, and bipolar sense electrodes 63 were coupled to the antrum of the stomach. Additionally, two stitch electrodes 66 with a strain gauge 68 located therebetween were coupled

to the antrum.

[0088] Reference is now made to Figs. 4, 5A and 5B, which are graphs showing the results of experiments performed using apparatus 60 in a rabbit, in accordance with a preferred embodiment of the present invention. Fig. 4 shows electrical activity in the fundus, measured during a five minute period before the rabbit was fed solid food, and during a more than six minute period while the rabbit was eating solid food. It can be seen that the second period is distinguished by markedly increased electrical activity. Spikes, typified by those marked "A," "B," and "C" in this graph, are preferably identified by a control unit operating in accordance with these embodiments of the present invention, and are interpreted as indications of eating. It is noted that in the case of the rabbit experiment shown in Fig. 4, electrical activity as measured by spikes per unit time increased by a factor of about 8, and is therefore considered to be a good indication of the initiation and continuation of eating.

[0089] Fig. 5A is a graph showing the electrical response of the fundus of the rabbit stomach, and the results of analysis thereof, in accordance with a preferred embodiment of the present invention. In this experiment, the measurements were first taken for five minutes while the rabbit was eating solid food, and were continued for almost 10 minutes after the rabbit ceased eating. It is clearly seen that the period after the rabbit ate is characterized by significantly less electrical activity than that which occurred during eating. Spikes, such as those marked "A," "B," and "C" in this graph, occur at a rate at least 15 times higher during eating than thereafter, and are therefore preferably used by a control unit to determine both the onset and the termination of eating.

[0090] Fig. 5B is an expanded view of some of the data shown in Fig. 5A, additionally showing simultaneous mechanical and electrical activity in the antrum of the rabbit. The top graph shows mechanical activity in the antrum as measured by strain gauge 68 (Fig. 3), and the middle graph shows electrical activity in the antrum, measured by electrodes 63 during the same time period. The repeated co-occurrence of antral mechanical and electrical activity, as seen in Fig. 5B, is indicative of the expected antral mechanical response to antral electrical activity.

[0091] The bottom graph of Fig. 5B shows the measured electrical activity in the fundus during the same period, i.e., while the rabbit was eating. It can be seen that, while there is close correlation between mechanical and electrical activity in the antrum, there is no correlation seen between fundic electrical activity and either measure of antral activity. Control unit 90 (Fig. 2) is therefore generally enabled to measure and differentiate between fundic and antral response, and to utilize this information to facilitate the evaluations and determinations described herein.

[0092] Fig. 6 is a graph showing electrical impedance measurements made between two stitch electrodes placed in the stomach of a pig, in accordance with a preferred embodiment of the present invention. In this experiment, fundic volume was measured at the same time as the impedance was measured, and the data show a clear dependence of the impedance on the volume. It is hypothesized that as the fundus distends, the fundic wall thickness decreases, producing a corresponding increase in electrical impedance. Alternatively or additionally, the increased distance between the two electrodes produced as a result of the distension causes the electrical impedance to increase. Similar experimental results (not shown) were obtained when impedance and volume measurements were made in the antrum. Moreover, changes in impedance were found to correlate with waves of antral activity.

[0093] Reference is now made to Figs. 7, 8, 9, and 10, which are graphs showing the results of experiments performed using apparatus (not shown) similar to apparatus 60 in several normal dogs, in accordance with a preferred embodiment of the present invention. All of the dogs fasted for approximately 24 hours prior to eating during the experiments.

[0094] Fig. 7 shows the rate of electrical events in the antrum in a dog, measured during a six minute period before the dog was fed solid food and during a more than seven minute period while the dog was eating solid food. Electrical events that were recorded were spikes in the signal of amplitude at least a threshold amount greater than the signal noise. It will be appreciated that detecting changes in other events may be useful for some applications. It will also be appreciated that whereas data shown in the figures reflects measurements of antral electrical events, for some applications the analysis techniques described herein may also be implemented with respect to the rate of fundic electrical events.

[0095] It can be seen that the second period is distinguished by a markedly decreased rate of antral electrical events. Such a decrease is preferably identified by a control unit operating in accordance with these embodiments of the present invention, and is interpreted as an indication of eating. It is noted that the rate of antral electrical events, as measured by events per unit time, decreased on average by about 20% beginning about one minute after the initiation of eating, and is therefore considered to be a good indication of the initiation and continuation of eating. (Decreases of up to about 50% were seen in other experiments.) Similar results were obtained in experiments on two other dogs (not shown).

[0096] Fig. 8 is a graph showing the rate of electrical events in the antrum in a second dog, measured during a more than 40 minute period before the dog was fed solid food, during an approximately 13 minute period while the dog was eating solid food (interrupted by an approximately 6 minute period of non-eating), and during an almost 60 minute period after the dog ceased eating. It is clearly seen that the period beginning approximately four minutes after the dog ceased eating is characterized by return to a rate of antral electrical events almost equal to the rate prior to eating, and significantly higher than the reduced rate during eating. The rate of antral electrical events is therefore preferably used by a control unit to determine both the onset and the termination of antral activity.

[0097] Fig. 9 is a graph showing simultaneous mechanical activity, electrical activity, and rate of electrical events in the antrum of a third dog, measured during a more than 16 minute period before the dog was fed solid food, during an approximately 3.5 minute period while the dog was eating solid food, and during a more than four minute period after the dog ceased eating. The top graph shows mechanical activity in the antrum as measured by a strain gauge, and the middle graph shows electrical activity in the antrum, measured by electrodes during the same time period. It can be seen that co-occurring mechanical and electrical activity began approximately 1.5 minutes prior to the beginning of eating, corresponding with the onset of cephalic phase activity (brain activity reflecting the mental anticipation of eating).

[0098] The bottom graph of Fig. 9 shows the rate of electrical events in the antrum of the dog. It can be seen that the second period is distinguished by a markedly decreased rate of antral electrical events, consistent with the results of the first dog experiment described hereinabove. An increase in mechanical and/or electrical antral activity prior to eating as occurred in this experiment is preferably identified by a control unit operating in accordance with these embodiments of the present invention, and provides additional information that can be interpreted together with information such as the decreased rate of antral electrical events observed in this experiment to provide indications of anticipation of eating, eating and/or gastric digestion.

[0099] Fig. 10 is a graph showing electrical impedance measurements made between two stitch electrodes in the fundus of a fourth dog, measured during five sequential periods: (1) an approximately 22 minute period before the dog was fed solid food (portion of period not shown), (2) an approximately three minute period while the dog was eating solid food, (3) an approximately 7.5 minute period during which the dog did not eat, (4) an approximately one minute period while the dog was eating solid food, and (5) a greater than 10 minute period after the dog ceased eating.

[0100] It can be seen that the eating periods (second and fourth periods) are distinguished by markedly increased fundic electrical impedance. Such increases are preferably identified by a control unit operating in accordance with these embodiments of the present invention, and are interpreted as indications of eating. This interpretation is supported by the correlation between impedance and volume measurements in the fundus obtained in the pig experiments described hereinabove. It is noted that in the case of the dog experiment shown in Fig. 10, the fundic electrical impedance, as measured in ohms, increased by more than about 12%, beginning less than about one minute after the initiation of eating during the second period, and by about 5% beginning less than about one minute after the initiation of eating during the fourth period. The fundic electrical impedance is therefore considered to be a good indication of the initiation and continuation of eating. Similar results were obtained in two other experiments on different days on the same dog (not shown).

[0101] It is clearly seen in Fig. 10 that the period beginning almost immediately after the dog ceased eating (the fifth period) is characterized by a return of fundic electrical impedance to a value almost equal to that prior to eating, and significantly lower than the increased value observed during eating. Fundic electrical impedance is therefore preferably used by a control unit to determine both the onset and the termination of eating.

[0102] The inventors have observed that fundic electrical impedance (e.g., as measured in the case of the dog experiment shown in Fig. 10), as an indicator of eating, typically exhibits lower variability than antral electrical impedance, and is less affected by movement and/or change in posture of the subject. Fundic electrical impedance also typically provides more reliable detection of eating than antral activity.

[0103] In preferred embodiments of the present invention, measurements of antral and/or fundic electrical impedance are used in conjunction with or separately from other indicators of swallowing or digestion, described hereinabove, in order to track a patient's eating habits. Advantageously, impedance measurements made between two electrodes located even at mutually remote sites on a portion of the stomach can be accurate indicators of global strain of that portion, while a mechanical strain gauge placed at a particular site on the stomach generally only yields an indication of strain at that site.

[0104] It will be recognized by persons skilled in the art that more complex combinations of variations in levels of electrical or mechanical activity in different regions of the stomach may occur than those demonstrated in the experiments described hereinabove. For example, certain electrical or mechanical activity may lag the eating of certain amounts and types of food. Examples of more complex combinations (not shown) were obtained in additional experiments in other dogs. Analysis block 80, with proper calibration as described hereinabove, can readily be enabled to evaluate such complex combinations.

[0105] It will be appreciated by persons skilled in the art that the present invention is not limited to what has been particularly shown and described hereinabove, but is limited only by the scope of the claims.

Claims

1. Gastric apparatus (18), comprising:

a gastrointestinal sensor (70, 72, 74), adapted to be coupled to a gastrointestinal site of a subject and to generate

a gastrointestinal sensor signal responsive to a property of the gastrointestinal site;
 a set of one or more implantable antral sensors (70, 74), adapted to be coupled to an antral site of an antrum
 of the stomach (20) and to generate an antral sensor signal responsive to a property of the antrum; and
 a control unit (90), adapted to receive and perform an analysis of the gastrointestinal and antral sensor signals,
 and to determine, responsive to the analysis, a characteristic of a food ingested by the subject **characterized**
in that the gastrointestinal sensor (70,72,74) comprises a set of one or more fundic sensors, adapted to be
 coupled to a fundic site of a fundus of the stomach of the subject and to generate a fundic sensor signal
 responsive to a property of the fundus, and wherein the control unit (90) is adapted to receive and analyze the
 fundic and antral sensor signals, and to determine, responsive thereto, the characteristic of the ingested food.

2. Apparatus according to claim 1, wherein the control unit (90) is adapted to determine, responsively to the analysis
 of the gastrointestinal and antral sensor signals, whether the ingested food is predominantly solid or liquid.

3. Apparatus according to claim 2, wherein the control unit (90) is adapted to:

determine, responsively to the gastrointestinal and antral sensor signals, a time delay between an onset of
 eating by the subject and a change in electrical activity in the antrum, and
 responsively to the delay, determine whether the ingested food is predominantly solid or liquid.

4. Apparatus according to claim 3, wherein the control unit (90) is adapted to determine whether the ingested food is
 predominantly solid or liquid, responsive to the time delay and responsive to a threshold time delay.

5. Apparatus according to claim 3, wherein the control unit is adapted to determine, responsive to the time delay, an
 extent to which the ingested food includes solid food matter.

6. Apparatus according to claim 5, wherein the control unit is adapted to determine that the ingested food includes
 solid food matter, responsive to the time delay being more than about one minute.

7. Apparatus according to claim 6, wherein the control unit is adapted to determine that the ingested food includes
 predominantly solid food matter, responsive to the time delay being more than about 5 minutes.

8. Apparatus according to claim 3, wherein the control unit is adapted to determine, responsive to the time delay, an
 extent to which the ingested food includes liquid food matter.

9. Apparatus according to claim 3, wherein the control unit (90) is adapted to detect, responsive to the fundic sensor
 signal, the onset of eating.

10. Apparatus according to claim 9, wherein the fundic sensor set comprises a set of fundic electrodes (74), adapted
 to generate a fundic electrode signal responsive to a property of the fundus, and wherein the antral sensor set
 comprises a set of antral electrodes (74), adapted to generate an antral electrode signal responsive to a property
 of the antrum, and wherein the control unit (90) is adapted to receive and analyze the fundic and antral electrode
 signals, and to determine, responsive thereto, the time delay.

11. Apparatus according to claim 10, wherein the antral electrode set comprises two antral electrodes, adapted to be
 coupled to two sites of the antrum, and wherein the control unit is adapted to identify a measure of electrical
 impedance between the two sites of the antrum.

12. Apparatus according to claim 10, wherein the control unit is adapted to determine the time delay between the onset
 of eating and an onset of a decreased rate of electrical events in the antrum.

13. Apparatus according to claim 10, wherein the control unit is adapted to determine the time delay between the onset
 of eating and an onset of increased electrical activity in the antrum.

14. Apparatus according to claim 10, wherein the control unit is adapted to determine the time delay between the onset
 of eating and a commencement of the electrical activity in the antrum.

15. Apparatus according to claim 10, wherein the fundic electrode set comprises two fundic electrodes, adapted to be
 coupled to two sites of the fundus, and wherein the control unit is adapted to identify a measure of electrical impedance

between the two sites of the fundus.

16. Apparatus according to claim 10, wherein the antral electrodes (74) are adapted to be coupled to the serosal layer of the stomach (20) and/or inserted into the muscular layer of the stomach (20).
17. Apparatus according to claim 10, wherein the fundic electrodes (74) are adapted to be coupled to the serosal layer of the stomach (20) and/or inserted into the muscular layer of the stomach (20).
18. Apparatus according to claim 1, wherein the fundic sensor set comprises a set of fundic electrodes, adapted to generate a fundic electrode signal responsive to a property of the fundus, and wherein the antral sensor set comprises a set of antral electrodes, adapted to generate an antral electrode signal responsive to a property of the antrum, and wherein the control unit is adapted to receive and analyze the fundic and antral electrode signals, and to determine, responsive thereto, the characteristic of the ingested food.
19. Apparatus according to claim 18, wherein the control unit is adapted to determine, responsive to an analysis of at least one of the electrode signals, an amount of the ingested food accumulated in a region of the stomach.
20. Apparatus according to claim 18, wherein the control unit is adapted to count, responsive to an analysis of at least one of the electrode signals, a number of meals ingested by the subject during a period of time.
21. Apparatus according to claim 18, wherein the antral electrode set comprises two antral electrodes, adapted to be coupled to two sites of the antrum, and wherein the control unit is adapted to identify a measure of electrical impedance between the two sites of the antrum.
22. Apparatus according to claim 18, wherein the fundic electrode set comprises two fundic electrodes, adapted to be coupled to two sites of the fundus, and wherein the control unit is adapted to identify a measure of electrical impedance between the two sites of the fundus.
23. Apparatus according to claim 22, wherein the control unit is adapted to identify a substantial return towards a baseline value of the measure of electrical impedance as indicative of a termination of eating.
24. Apparatus according to claim 18, wherein the control unit is adapted to perform a calibration including measurement of a response of the fundic and antral electrode signals to ingestion by the subject of one or more test foods.
25. Apparatus according to claim 18, wherein the antral electrode set is adapted to generate the antral electrode signal responsive to an electrical potential change generated responsive to a contraction of a muscle of the antrum.
26. Apparatus according to claim 25, wherein the control unit is adapted to determine the characteristic of the ingested food responsive to an amplitude of the antral electrode signal, a frequency of the antral electrode signal, a spike energy per antral cycle of electrical activity, a duration of the antral electrode signal, or a change in a rate of antral electrode signal events.
27. Apparatus according to claim 25, wherein the control unit is adapted to identify a substantial return towards a baseline value of an amplitude of the antral electrode signal as indicative of a termination of antral digestion.
28. Apparatus according to claim 25, wherein the control unit is adapted to identify a substantial return towards a baseline value of a rate of antral electrode signal events as indicative of a termination of antral digestion.
29. Apparatus according to claim 18, wherein the fundic electrode set is adapted to generate the fundic electrode signal responsive to an electrical potential change generated responsive to a contraction of a muscle of the fundus.
30. Apparatus according to claim 29, wherein the control unit is adapted to determine the characteristic of the ingested food responsive to an amplitude of the fundic electrode signal, a frequency of the fundic electrode signal a duration of the fundic electrode signal, or a change in a rate of fundic electrode signal events.
31. Apparatus according to claim 29, wherein the control unit is adapted to identify a substantial return towards a baseline value of an amplitude of the fundic electrode signal as indicative of a termination of eating.

32. Apparatus according to claim 29, wherein the control unit is adapted to identify a substantial return towards a baseline value of a frequency of the fundic electrode signal as indicative of a termination of eating.

33. Apparatus according to any one of claims 1, 2 or 3, and comprising a set of one or more current-application electrodes (100), adapted to be coupled to a tissue of the subject, and wherein the control unit (90) is adapted to drive a current, responsive to the analysis, through the set of current-application electrodes into the tissue.

34. Apparatus according to claim 33, wherein the control unit (90) is adapted to configure the current to induce a feeling of satiation.

35. Apparatus according to claim 33, wherein the current-application electrode set is adapted to be placed at a site of the stomach (20) of the subject.

36. Apparatus according to claim 33, wherein the control unit (90) is adapted to drive the current-application electrode set to apply an Excitable-Tissue Control (ETC) signal to the tissue.

37. A method comprising:

sensing a property of a gastrointestinal site;
sensing a property of an antrum of the stomach using a set of one or more implantable antral sensors;
performing an analysis of the property of the gastrointestinal site and the property of the antrum; and
determining, responsive to the analysis, a characteristic of a food ingested by the subject, wherein determining the characteristic of the food comprises determining, responsively to the analysis of gastrointestinal and antral properties, whether the ingested food is predominantly solid or liquid and wherein determining whether the ingested food is predominantly solid or liquid comprises:

determining, responsively to the analysis of gastrointestinal and antral properties, a time delay between an onset of eating by the subject and a change in electrical activity in the antrum; and
responsively to the delay, determining whether the ingested food is predominantly solid or liquid **characterised in that** sensing the property of the gastrointestinal tract comprises sensing a property of a fundus of the stomach.

38. A method according to claim 37, wherein determining the time delay comprises determining the time delay between the onset of eating and an onset of a decreased rate of electrical events in the antrum.

39. A method according to claim 37, wherein determining the time delay comprises determining the time delay between the onset of eating and an onset of eating and an onset of increased electrical activity in the antrum.

40. A method according to any one of claims 37 to 39, wherein sensing the property of the fundus comprises sensing an electrical current in the fundus, and wherein sensing the property of the antrum comprises sensing an electrical current in the antrum.

41. A method according to claim 40, wherein sensing the electrical current in the fundus comprises sensing the electrical current using a set of one or more fundic electrodes coupled to the serosal layer of the stomach (20) and/or inserted into the muscular layer of the stomach.

42. A method according to claim 40, wherein sensing the electrical current in the antrum comprises sensing the electrical current using a set of one or more antral electrodes coupled to the serosal layer of the stomach (20) and/or inserted into the muscular layer of the stomach.

43. A method according to claim 40, wherein sensing the current in the fundus comprises sensing a current indicative of a measure of electrical impedance between two sites of the fundus.

Patentansprüche

1. Magengerät (18), umfassend:

einen gastrointestinalen Sensor (70, 72, 74), der ausgelegt ist, um mit einer gastrointestinalen Stelle eines Subjekts gekoppelt zu werden, und um ein Signal des gastrointestinalen Sensors zu erzeugen, das auf eine Eigenschaft der gastrointestinalen Stelle reagiert;

einen Satz aus einem oder aus mehreren implantierbaren Antrumsensoren (70, 74), die ausgelegt sind, um an eine Antrumstelle eines Antrums des Magens (20) gekoppelt zu werden, und um ein Signal des Antrumsensors zu erzeugen, das auf eine Eigenschaft des Antrums reagiert; und

eine Steuereinheit (90), die ausgelegt ist, um eine Analyse der Signale des gastrointestinalen und des Antrumsensors zu empfangen und durchzuführen, und, in Reaktion auf die Analyse, eine Eigenschaft eines Nahrungsmittels zu bestimmen, die vom Subjekt aufgenommen wurde, **dadurch gekennzeichnet, dass** der gastrointestinale Sensor (70, 72, 74) einen Satz von einem oder von mehreren Fundussensoren umfasst, die ausgelegt sind, um mit einer Fundusstelle eines Fundus des Magens des Subjekts gekoppelt zu werden, und um ein Signal des Fundussensors zu erzeugen, das auf eine Eigenschaft des Fundus reagiert, und wobei die Steuereinheit (90) ausgelegt ist, um die Signale des Fundus- und des Antrumsensors zu erhalten und zu analysieren, und um in Reaktion darauf die Eigenschaft des aufgenommenen Nahrungsmittels zu bestimmen.

2. Gerät nach Anspruch 1, wobei die Steuereinheit (90) ausgelegt ist, um in Reaktion auf die Analyse Signale des gastrointestinalen und des Antrumsensors zu bestimmen, ob das aufgenommene Nahrungsmittel vorwiegend fest oder flüssig ist.
3. Gerät nach Anspruch 2, wobei die Steuereinheit (90) ausgelegt ist, um in Reaktion auf die Signale des gastrointestinalen und des Antrumsensors eine Zeitverzögerung zwischen einem Beginn der Nahrungsaufnahme durch das Subjekt und einer Änderung der elektrischen Aktivität im Antrum zu bestimmen und, in Reaktion auf die Verzögerung, zu bestimmen, ob das aufgenommene Nahrungsmittel vorwiegend fest oder flüssig ist.
4. Gerät nach Anspruch 3, wobei die Steuereinheit (90) ausgelegt ist, um zu bestimmen, ob das aufgenommene Nahrungsmittel vorwiegend fest oder flüssig ist, in Reaktion auf die Zeitverzögerung und in Reaktion auf einen Zeitverzögerungs-Schwelle.
5. Gerät nach Anspruch 3, wobei die Steuereinheit ausgelegt ist, um in Reaktion auf die Zeitverzögerung, einen Grad zu bestimmen, bis zu dem das aufgenommene Nahrungsmittel feste Nahrungssubstanzen umfasst.
6. Gerät nach Anspruch 5, wobei die Steuereinheit ausgelegt ist, um festzustellen, dass das aufgenommene Nahrungsmittel feste Nahrungssubstanzen umfasst, in Reaktion darauf, dass die Zeitverzögerung mehr als ungefähr eine Minute beträgt.
7. Gerät nach Anspruch 6, wobei die Steuereinheit ausgelegt ist, um festzustellen, dass das aufgenommene Nahrungsmittel vorwiegend feste Nahrungssubstanzen umfasst, in Reaktion darauf, dass die Zeitverzögerung mehr als ungefähr 5 Minuten beträgt.
8. Gerät nach Anspruch 3, wobei die Steuereinheit ausgelegt ist, um, in Reaktion auf die Zeitverzögerung, einen Grad zu bestimmen, bis zu dem das aufgenommene Nahrungsmittel flüssige Nahrungssubstanzen umfasst.
9. Gerät nach Anspruch 3, wobei die Steuereinheit (90) ausgelegt ist, um, in Reaktion auf das Signal des Fundussensors den Beginn der Nahrungsaufnahme nachzuweisen.
10. Gerät nach Anspruch 9, wobei der Fundussensorsatz einen Satz von Funduselektroden (74) umfasst, die ausgelegt sind, um ein Signal der Funduselektrode in Reaktion auf eine Eigenschaft des Fundus zu erzeugen, und wobei ein Antrumsensorsatz einen Satz von Antrumelektroden (74) umfasst, die ausgelegt sind, um ein Signal der Antrumelektrode in Reaktion auf eine Eigenschaft des Antrums zu erzeugen, und wobei die Steuereinheit (90) ausgelegt ist, um die Signale der Fundus- und der Antrumelektrode zu erhalten und zu analysieren, und um in Reaktion darauf die Zeitverzögerung zu bestimmen.
11. Gerät nach Anspruch 10, wobei der Antrumelektrodensatz zwei Antrumelektroden umfasst, die ausgelegt sind, um mit zwei Stellen des Antrums gekoppelt zu werden, und wobei die Steuereinheit ausgelegt ist, um eine Messung der elektrischen Impedanz zwischen den zwei Stellen des Antrums zu identifizieren.

12. Gerät nach Anspruch 10, wobei die Steuervorrichtung ausgelegt ist, um die Zeitverzögerung zwischen dem Beginn der Nahrungsaufnahme und dem Beginn einer verringerten Rate von elektrischen Ereignissen im Antrum zu bestimmen.
- 5 13. Gerät nach Anspruch 10, wobei die Steuervorrichtung ausgelegt ist, um die Zeitverzögerung zwischen dem Beginn der Nahrungsaufnahme und einem Beginn einer erhöhten Rate von elektrischer Aktivität im Antrum zu bestimmen.
14. Gerät nach Anspruch 10, wobei die Steuervorrichtung ausgelegt ist, um die Zeitverzögerung zwischen dem Beginn der Nahrungsaufnahme und einem Beginn der elektrischen Aktivität im Antrum zu bestimmen.
- 10 15. Gerät nach Anspruch 10, wobei der Funduselektrodensatz zwei Funduselektroden umfasst, die ausgelegt sind, um mit zwei Stellen des Fundus gekoppelt zu werden, und wobei die Steuereinheit ausgelegt ist, um eine Messung der elektrischen Impedanz zwischen den zwei Stellen des Fundus zu identifizieren.
- 15 16. Gerät nach Anspruch 10, wobei die Antrumelektroden (74) ausgelegt sind, um mit der Serosaschicht des Magens (20) gekoppelt und/oder in die Muskelschicht des Magens (20) eingeführt zu werden.
17. Gerät nach Anspruch 10, wobei die Funduselektroden (74) ausgelegt sind, um mit der Serosaschicht des Magens (20) gekoppelt und/oder in die Muskelschicht des Magens (20) eingeführt zu werden.
- 20 18. Gerät nach Anspruch 1, wobei der Fundussensorsatz einen Satz von Funduselektroden umfasst, sie ausgelegt sind, um ein Signal der Funduselektrode in Reaktion auf eine Eigenschaft des Fundus zu erzeugen, und wobei der Antrumsensorsatz einen Satz von Antrumelektroden umfasst, sie ausgelegt sind, um ein Signal der Antrumelektrode in Reaktion auf eine Eigenschaft des Antrums zu erzeugen, und wobei die Steuereinheit ausgelegt ist, um die Signale der Fundus- und der Antrumelektrode zu erhalten und zu analysieren, und um in Reaktion darauf die Eigenschaft der aufgenommenen Nahrungsmittel zu bestimmen.
- 25 19. Gerät nach Anspruch 18, wobei die Steuereinheit ausgelegt ist, um in Reaktion auf eine Analyse von mindestens einem der Elektrodensignale eine Menge des aufgenommenen Nahrungsmittels zu bestimmen, die in einer Region des Magens angesammelt ist.
- 30 20. Gerät nach Anspruch 18, wobei die Steuervorrichtung ausgelegt ist, um in Reaktion auf eine Analyse von mindestens einem der Elektrodensignale die Anzahl der Mahlzeiten zu zählen, die vom Subjekt während eines Zeitraums aufgenommen wurden.
- 35 21. Gerät nach Anspruch 18, wobei der Antrumelektrodensatz zwei Antrumelektroden umfasst, die ausgelegt sind, um mit zwei Stellen des Antrums gekoppelt zu werden, und wobei die Steuereinheit ausgelegt ist, um eine Messung der elektrischen Impedanz zwischen den zwei Stellen des Antrums zu identifizieren.
- 40 22. Gerät nach Anspruch 18, wobei der Funduselektrodensatz zwei Funduselektroden umfasst, die ausgelegt sind, um mit zwei Stellen des Fundus gekoppelt zu werden, und wobei die Steuereinheit ausgelegt ist, um eine Messung der elektrischen Impedanz zwischen den zwei Stellen des Fundus zu identifizieren.
- 45 23. Gerät nach Anspruch 22, wobei die Steuereinheit ausgelegt ist, um eine wesentliche Rückkehr zu einem Grundwert der Messung der elektrischen Impedanz als Hinweis auf eine Beendigung der Nahrungsaufnahme zu identifizieren.
24. Gerät nach Anspruch 18, wobei die Steuereinheit ausgelegt ist, um eine Kalibrierung, darin eingeschlossen die Messung, einer Reaktion der Signale der Fundus und Antrumelektrode auf die Nahrungsaufnahme durch das Subjekt von einem oder mehreren Test-Nahrungsmitteln durchzuführen.
- 50 25. Gerät nach Anspruch 18, wobei der Antrumelektrodensatz ausgelegt ist, um das Signals der Antrumelektrode in Reaktion auf eine Änderung des elektrischen Potenzials zu erzeugen, die in Reaktion auf eine Kontraktion eines Muskels des Antrums erzeugt wird.
- 55 26. Gerät nach Anspruch 25, wobei die Steuervorrichtung ausgelegt ist, um die Eigenschaft des aufgenommenen Nahrungsmittels in Reaktion auf eine Amplitude des Signals der Antrumelektrode, eine Frequenz des Signals der Antrumelektrode, eine Zackenenergie pro Antrumzyklus der elektrischen Aktivität, eine Dauer des Signals der Antrumelektrode oder einer Änderung einer Rate der Ereignisse des Signals der Antrumelektrode zu bestimmen.

27. Gerät nach Anspruch 25, wobei die Steuereinheit ausgelegt ist, um eine wesentliche Rückkehr zu einem Grundwert einer Amplitude des Signals der Antrumelektrode, als Hinweis auf eine Beendigung der Antrumverdauung zu identifizieren

28. Gerät nach Anspruch 25, wobei die Steuereinheit ausgelegt ist, um eine wesentliche Rückkehr zu einem Grundwert einer Rate der Ereignisse des Signals der Antrumelektrode als Hinweis auf die Beendigung der Antrumverdauung zu identifizieren

29. Gerät nach Anspruch 18, wobei der Funduselektrodensatz ausgelegt ist, um das Signal der Funduselektrode in Reaktion auf eine Änderung des elektrischen Potenzials zu erzeugen, die in Reaktion auf eine Kontraktion eines Muskels des Fundus erzeugt wird.

30. Gerät nach Anspruch 29, wobei die Steuervorrichtung ausgelegt ist, um die Eigenschaft des aufgenommenen Nahrungsmittels in Reaktion auf eine Amplitude des Signals der Funduselektrode, eine Frequenz des Signals der Funduselektrode, eine Dauer des Signals der Funduselektrode oder einer Änderung der Rate der Ereignisse des Signals der Funduselektrode zu bestimmen.

31. Gerät nach Anspruch 29, wobei die Steuervorrichtung ausgelegt ist, um eine wesentliche Rückkehr zu einem Grundwert einer Amplitude des Signals der Funduselektrode, als Hinweis auf eine Beendigung der Nahrungsaufnahme zu identifizieren.

32. Gerät nach Anspruch 29, wobei die Steuereinheit ausgelegt ist, um eine wesentliche Rückkehr zu einem Grundwert einer Frequenz des Signals der Funduselektrode, als Hinweis auf eine Beendigung der Nahrungsaufnahme zu identifizieren.

33. Gerät nach einem der Ansprüche 1, 2 oder 3, und umfassend einen Satz von einer oder von mehreren Stromapplikationselektroden (100), die ausgelegt sind, um an ein Gewebe des Subjekts gekoppelt zu werden, und wobei die Steuereinheit (90) ausgelegt ist, um einen Strom in Reaktion auf die Analyse durch den Satz von Stromapplikationselektroden in das Gewebe zu führen.

34. Gerät nach Anspruch 33, wobei die Steuervorrichtung (90) ausgelegt ist, um den Strom zu konfigurieren, um ein Gefühl der Sättigung zu induzieren.

35. Gerät nach Anspruch 33, wobei das Stromapplikationselektroden-Set ausgelegt ist, um an einer Stelle des Magens (20) des Subjekts angeordnet zu werden.

36. Gerät nach Anspruch 33, wobei die Steuervorrichtung (90) ausgelegt ist, um das Stromapplikationselektroden-Set anzutreiben, um ein Excitable Tissue Control (ETC)-Signal an das Gewebe anzulegen.

37. Verfahren, umfassend:

Erfassung einer Eigenschaft einer gastrointestinalen Stelle;

Erfassung einer Eigenschaft eines Antrums des Magens unter Verwendung eines Satzes von einem oder von mehreren implantierbaren Antrumsensoren;

Durchführung einer Analyse der Eigenschaft der gastrointestinalen Stelle und der Eigenschaft des Antrums; und Bestimmung, in Reaktion auf die Analyse, einer Eigenschaft eines Nahrungsmittels, das vom Subjekt aufgenommen wurde, wobei die Bestimmung der Eigenschaft des Nahrungsmittels die Bestimmung, in Reaktion auf die Analyse der gastrointestinalen und der Antrumeigenschaften, umfasst, ob das aufgenommene Nahrungsmittel vorwiegend fest oder flüssig ist, und wobei die Bestimmung, ob das aufgenommene Nahrungsmittel vorwiegend fest oder flüssig ist, Folgendes umfasst:

Bestimmung, in Reaktion auf die Analyse der gastrointestinalen und der Antrumeigenschaften, einer Zeitverzögerung zwischen einem Beginn der Nahrungsaufnahme durch das Subjekt und einer Änderung der elektrischen Aktivität im Antrum; und

in Reaktion auf die Verzögerung, Bestimmung, ob das aufgenommene Nahrungsmittel vorwiegend fest oder flüssig ist, **dadurch gekennzeichnet, dass** die Erfassung der Eigenschaft des Gastrointestinaltrakts die Erfassung einer Eigenschaft eines Fundus des Magens umfasst.

38. Verfahren nach Anspruch 37, wobei die Bestimmung der Zeitverzögerung die Bestimmung der Zeitverzögerung zwischen dem Beginn der Nahrungsaufnahme und dem Beginn einer verringerten Rate von elektrischen Ereignissen im Antrum umfasst.

39. Verfahren nach Anspruch 37, wobei die Bestimmung der Zeitverzögerung die Bestimmung der Zeitverzögerung zwischen dem Beginn der Nahrungsaufnahme und einem Beginn der Nahrungsaufnahme und einem Beginn einer erhöhten Rate von elektrischen Ereignissen im Antrum umfasst.

40. Verfahren nach einem der Ansprüche 37 bis 39, wobei die Erfassung der Eigenschaft des Fundus die Erfassung eines elektrischen Stroms im Fundus umfasst, und wobei die Erfassung der Eigenschaft des Antrums die Erfassung eines elektrischen Stroms im Antrum umfasst.

41. Verfahren nach Anspruch 40, wobei die Erfassung des elektrischen Stroms im Fundus die Erfassung des elektrischen Stroms unter Verwendung von einer oder von mehreren Funduselektroden umfasst, die mit der Serosaschicht des Magens (20) gekoppelt und/oder in die Muskelschicht des Magens eingeführt sind.

42. Verfahren nach Anspruch 40, wobei die Erfassung des elektrischen Stroms im Antrum die Erfassung des elektrischen Stroms unter Verwendung eines Satzes von einer oder von mehreren Antrumelektroden umfasst, die mit der Serosaschicht des Magens (20) gekoppelt und/oder in die Muskelschicht des Magens eingeführt sind.

43. Verfahren nach Anspruch 40, wobei die Erfassung des elektrischen Stroms im Fundus die Erfassung eines Stroms umfasst, der auf eine Messung der elektrischen Impedanz zwischen zwei Stellen des Fundus hinweist.

Revendications

1. Appareil gastrique (18), comprenant :

un capteur gastro-intestinal (70, 72, 74), conçu pour être couplé à un site gastro-intestinal d'un sujet et pour générer un signal de capteur gastro-intestinal en réponse à une propriété du site gastro-intestinal ;

un ensemble d'un ou de plusieurs capteurs antraux implantables (70, 74), conçus pour être couplés à un site antral d'un antre de l'estomac (20) et pour générer un signal de capteur antral en réponse à une propriété de l'antre ; et

une unité de commande (90), conçue pour recevoir les signaux de capteurs gastro-intestinal et antral et effectuer une analyse de ceux-ci, et pour déterminer, en réponse à l'analyse, une caractéristique d'un aliment ingéré par le sujet, **caractérisé en ce que** le capteur gastro-intestinal (70, 72, 74) comprend un ensemble d'un ou de plusieurs capteurs fundiques, conçus pour être couplés à un site fundique d'un fundus de l'estomac du sujet et pour générer un signal de capteur fundique en réponse à une propriété du fundus, et dans lequel l'unité de commande (90) est conçue pour recevoir les signaux de capteurs fundique et antral et les analyser, et pour déterminer, en réponse à ceux-ci, la caractéristique de l'aliment ingéré.

2. Appareil selon la revendication 1, dans lequel l'unité de commande (90) est conçue pour déterminer, en réponse à l'analyse des signaux de capteurs gastro-intestinal et antral, si l'aliment ingéré est principalement solide ou liquide.

3. Appareil selon la revendication 2, dans lequel l'unité de commande (90) est conçue pour :

déterminer, en réponse aux signaux de capteurs gastro-intestinal et antral, un retard entre un commencement d'alimentation du sujet et une modification de l'activité électrique dans l'antre, et en réponse au retard, déterminer si l'aliment ingéré est principalement solide ou liquide.

4. Appareil selon la revendication 3, dans lequel l'unité de commande (90) est conçue pour déterminer si l'aliment ingéré est principalement solide ou liquide, en réponse au retard et en réponse à un seuil de retard.

5. Appareil selon la revendication 3, dans lequel l'unité de commande est conçue pour déterminer, en réponse au retard, dans quelle mesure l'aliment ingéré comprend une matière alimentaire solide.

6. Appareil selon la revendication 5, dans lequel l'unité de commande est conçue pour déterminer que l'aliment ingéré comprend une matière alimentaire solide en réponse au fait que le retard est supérieur à environ une minute.

7. Appareil selon la revendication 6, dans lequel l'unité de commande est conçue pour déterminer que l'aliment ingéré comprend principalement une matière alimentaire solide en réponse au fait que le retard est supérieur à environ 5 minutes.
- 5 8. Appareil selon la revendication 3, dans lequel l'unité de commande est conçue pour déterminer, en réponse au retard, dans quelle mesure l'aliment ingéré comprend une matière alimentaire liquide.
9. Appareil selon la revendication 3, dans lequel l'unité de commande (90) est conçue pour détecter, en réponse au signal de capteur fundique, le commencement de l'alimentation.
- 10 10. Appareil selon la revendication 9, dans lequel l'ensemble de capteurs fundiques comprend un ensemble d'électrodes fundiques (74), conçues pour générer un signal d'électrode fundique en réponse à une propriété du fundus, et dans lequel l'ensemble de capteurs antraux comprend un ensemble d'électrodes antrales (74), conçues pour générer un signal d'électrode antrale en réponse à une propriété de l'antré, et dans lequel l'unité de commande (90) est conçue pour recevoir les signaux d'électrodes fundiques et antrales, et pour déterminer le retard en réponse à ceux-ci.
- 15 11. Appareil selon la revendication 10, dans lequel l'ensemble d'électrodes antrales comprend deux électrodes antrales, conçues pour être couplées à deux sites de l'antré, et dans lequel l'unité de commande est conçue pour identifier une mesure de l'impédance électrique entre les deux sites de l'antré.
- 20 12. Appareil selon la revendication 10, dans lequel l'unité de commande est conçue pour déterminer le retard entre le commencement de l'alimentation et un commencement d'un taux réduit d'événements électriques dans l'antré.
- 25 13. Appareil selon la revendication 10, dans lequel l'unité de commande est conçue pour déterminer le retard entre le commencement de l'alimentation et un commencement d'une activité électrique accrue dans l'antré.
- 30 14. Appareil selon la revendication 10, dans lequel l'unité de commande est conçue pour déterminer le retard entre le commencement de l'alimentation et un commencement de l'activité électrique dans l'antré.
- 35 15. Appareil selon la revendication 10, dans lequel l'ensemble d'électrodes fundiques comprend deux électrodes fundiques, conçues pour être couplées à deux sites du fundus, et dans lequel l'unité de commande est conçue pour identifier une mesure de l'impédance électrique entre les deux sites du fundus.
16. Appareil selon la revendication 10, dans lequel les électrodes antrales (74) sont conçues pour être couplées à la couche séreuse de l'estomac (20) et/ou insérées dans la couche musculaire de l'estomac (20).
17. Appareil selon la revendication 10, dans lequel les électrodes fundiques (74) sont conçues pour être couplées à la couche séreuse de l'estomac (20) et/ou insérées dans la couche musculaire de l'estomac (20).
- 40 18. Appareil selon la revendication 1, dans lequel l'ensemble de capteurs fundiques comprend un ensemble d'électrodes fundiques, conçues pour générer un signal d'électrode fundique en réponse à une propriété du fundus, et dans lequel l'ensemble de capteurs antraux comprend un ensemble d'électrodes antrales, conçues pour générer un signal d'électrode antrale en réponse à une propriété de l'antré, et dans lequel l'unité de commande est conçue pour recevoir les signaux d'électrodes fundiques et antrales et les analyser, et pour déterminer, en réponse à ceux-ci, la caractéristique de l'aliment ingéré.
- 45 19. Appareil selon la revendication 18, dans lequel l'unité de commande est conçue pour déterminer, en réponse à une analyse d'au moins l'un des signaux d'électrodes, une quantité de l'aliment ingéré accumulée dans une région de l'estomac.
- 50 20. Appareil selon la revendication 18, dans lequel l'unité de commande est conçue pour compter, en réponse à une analyse d'au moins l'un des signaux d'électrodes, un nombre de repas ingérés par le sujet pendant une période de temps.
- 55 21. Appareil selon la revendication 18, dans lequel l'ensemble d'électrodes antrales comprend deux électrodes antrales, conçues pour être couplées à deux sites de l'antré, et dans lequel l'unité de commande est conçue pour identifier une mesure de l'impédance électrique entre les deux sites de l'antré.

22. Appareil selon la revendication 18, dans lequel l'ensemble d'électrodes fundiques comprend deux électrodes fundiques, conçues pour être couplées à deux sites du fundus, et dans lequel l'unité de commande est conçue pour identifier une mesure de l'impédance électrique entre les deux sites du fundus.
- 5 23. Appareil selon la revendication 22, dans lequel l'unité de commande est conçue pour identifier un retour sensible vers une valeur de ligne de base de la mesure de l'impédance électrique comme étant indicatif d'une fin d'alimentation.
24. Appareil selon la revendication 18, dans lequel l'unité de commande est conçue pour effectuer un étalonnage comprenant la mesure d'une réponse des signaux d'électrodes fundiques et antrales à l'ingestion par le sujet d'un
10 ou de plusieurs aliments de test.
25. Appareil selon la revendication 18, dans lequel l'ensemble d'électrodes antrales est conçu pour générer le signal d'électrode antrale en réponse à une variation de potentiel électrique générée en réponse à une contraction d'un
15 muscle de l'antrale.
26. Appareil selon la revendication 25, dans lequel l'unité de commande est conçue pour déterminer la caractéristique de l'aliment ingéré en réponse à une amplitude du signal d'électrode antrale, à une fréquence du signal d'électrode antrale, à un pic d'énergie par cycle antral de l'activité électrique, à une durée du signal d'électrode antrale, ou à
20 une variation d'un taux d'événements de signal d'électrode antrale.
27. Appareil selon la revendication 25, dans lequel l'unité de commande est conçue pour identifier un retour sensible vers une valeur de ligne de base d'une amplitude du signal d'électrode antrale comme étant indicatif d'une fin de la digestion antrale.
- 25 28. Appareil selon la revendication 25, dans lequel l'unité de commande est conçue pour identifier un retour sensible vers une valeur de ligne de base d'un taux d'événements de signal d'électrode antrale comme étant indicatif d'une fin de la digestion antrale.
29. Appareil selon la revendication 18, dans lequel l'ensemble d'électrodes fundiques est conçu pour générer le signal d'électrode fundique en réponse à une variation de potentiel électrique générée en réponse à une contraction d'un
30 muscle du fundus.
30. Appareil selon la revendication 29, dans lequel l'unité de commande est conçue pour déterminer la caractéristique de l'aliment ingéré en réponse à une amplitude du signal d'électrode fundique, à une fréquence du signal d'électrode fundique, à une durée du signal d'électrode fundique, ou à une variation d'un taux d'événements de signal d'électrode fundique.
35
31. Appareil selon la revendication 29, dans lequel l'unité de commande est conçue pour identifier un retour sensible vers une valeur de ligne de base d'une amplitude du signal d'électrode fundique comme étant indicatif d'une fin d'alimentation.
40
32. Appareil selon la revendication 29, dans lequel l'unité de commande est conçue pour identifier un retour sensible vers une valeur de ligne de base d'une fréquence du signal d'électrode fundique comme étant indicatif d'une fin d'alimentation.
45
33. Appareil selon l'une quelconque des revendications 1, 2 ou 3, comprenant un ensemble d'une ou de plusieurs électrodes d'application de courant (100), conçues pour être couplées à un tissu du sujet, et dans lequel l'unité de commande (90) est conçue pour commander un courant, en réponse à l'analyse, par l'intermédiaire de l'ensembles d'électrodes d'application de courant dans le tissu.
50
34. Appareil selon la revendication 33, dans lequel l'unité de commande (90) est conçue pour configurer le courant pour induire une sensation de satiété.
35. Appareil selon la revendication 33, dans lequel l'ensemble d'électrodes d'application de courant est conçu pour être
55 placé au niveau d'un site de l'estomac (20) du sujet.
36. Appareil selon la revendication 33, dans lequel l'unité de commande (90) est conçue pour commander l'ensemble d'électrodes d'application de courant pour appliquer un signal de commande de tissu excitable (ETC) au tissu.

37. Procédé comprenant :

la détection d'une propriété d'un site gastro-intestinal ;
la détection d'une propriété d'un antrum de l'estomac en utilisant un ensemble d'un ou de plusieurs capteurs
antraux implantables ;
l'exécution d'une analyse de la propriété du site gastro-intestinal et de la propriété de l'antrum ; et
la détermination, en réponse à l'analyse, d'une caractéristique d'un aliment ingéré par le sujet, dans lequel la
détermination de la caractéristique de l'aliment comprend la détermination, en réponse à l'analyse des propriétés
gastro-intestinales et antrales, si l'aliment ingéré est principalement solide ou liquide, et dans lequel la déter-
mination si l'aliment ingéré est principalement solide ou liquide comprend :

la détermination, en réponse à l'analyse des propriétés gastro-intestinales et antrales, d'un retard entre un
commencement d'alimentation du sujet et une variation de l'activité électrique dans l'antrum ; et
en réponse au retard, la détermination si l'aliment ingéré est principalement solide ou liquide, **caractérisé**
en ce que la détection de la propriété du tube gastro-intestinal comprend la détection d'une propriété d'un
fundus de l'estomac.

38. Procédé selon la revendication 37, dans lequel la détermination du retard comprend la détermination du retard entre
le commencement de l'alimentation et un commencement d'un taux réduit d'événements électriques dans l'antrum.

39. Procédé selon la revendication 37, dans lequel la détermination du retard comprend la détermination du retard entre
le commencement de l'alimentation et un commencement d'une activité électrique accrue dans l'antrum.

40. Procédé selon l'une quelconque des revendications 37 à 39, dans lequel la détection de la propriété du fundus
comprend la détection d'un courant électrique dans le fundus, et dans lequel la détection de la propriété de l'antrum
comprend la détection d'un courant électrique dans l'antrum.

41. Procédé selon la revendication 40, dans lequel la détection du courant électrique dans le fundus comprend la
détection du courant électrique en utilisant un ensemble d'une ou de plusieurs électrodes fundiques couplées à la
couche séreuse de l'estomac (20) et/ou insérées dans la couche musculaire de l'estomac.

42. Procédé selon la revendication 40, dans lequel la détection du courant électrique dans l'antrum comprend la détection
du courant électrique en utilisant un ensemble d'une ou de plusieurs électrodes antrales couplées à la couche
séreuse de l'estomac (20) et/ou insérées dans la couche musculaire de l'estomac.

43. Procédé selon la revendication 40, dans lequel la détection du courant dans le fundus comprend la détection d'un
courant indicatif d'une mesure de l'impédance électrique entre deux sites du fundus.

FIG. 1

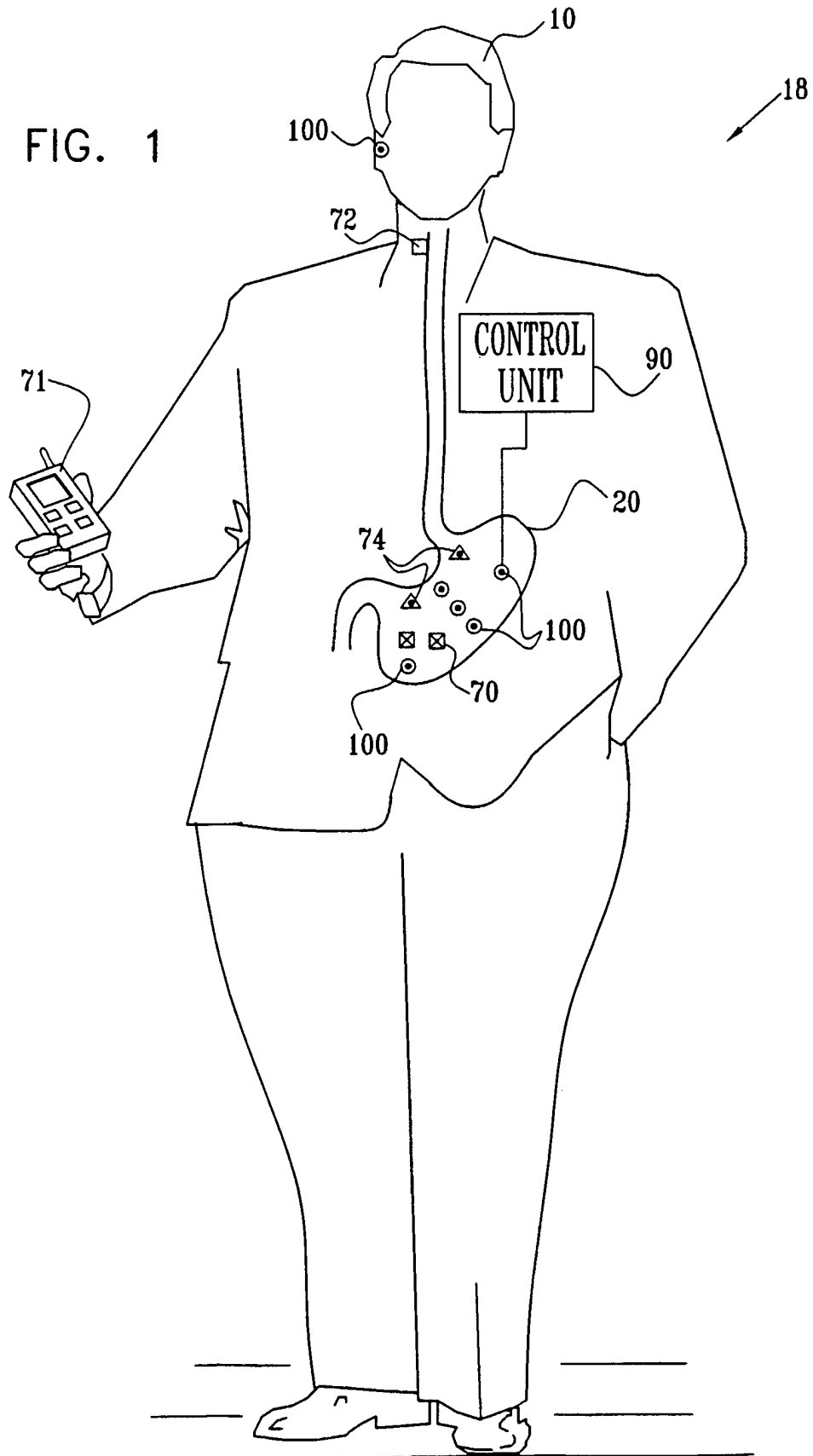


FIG. 2

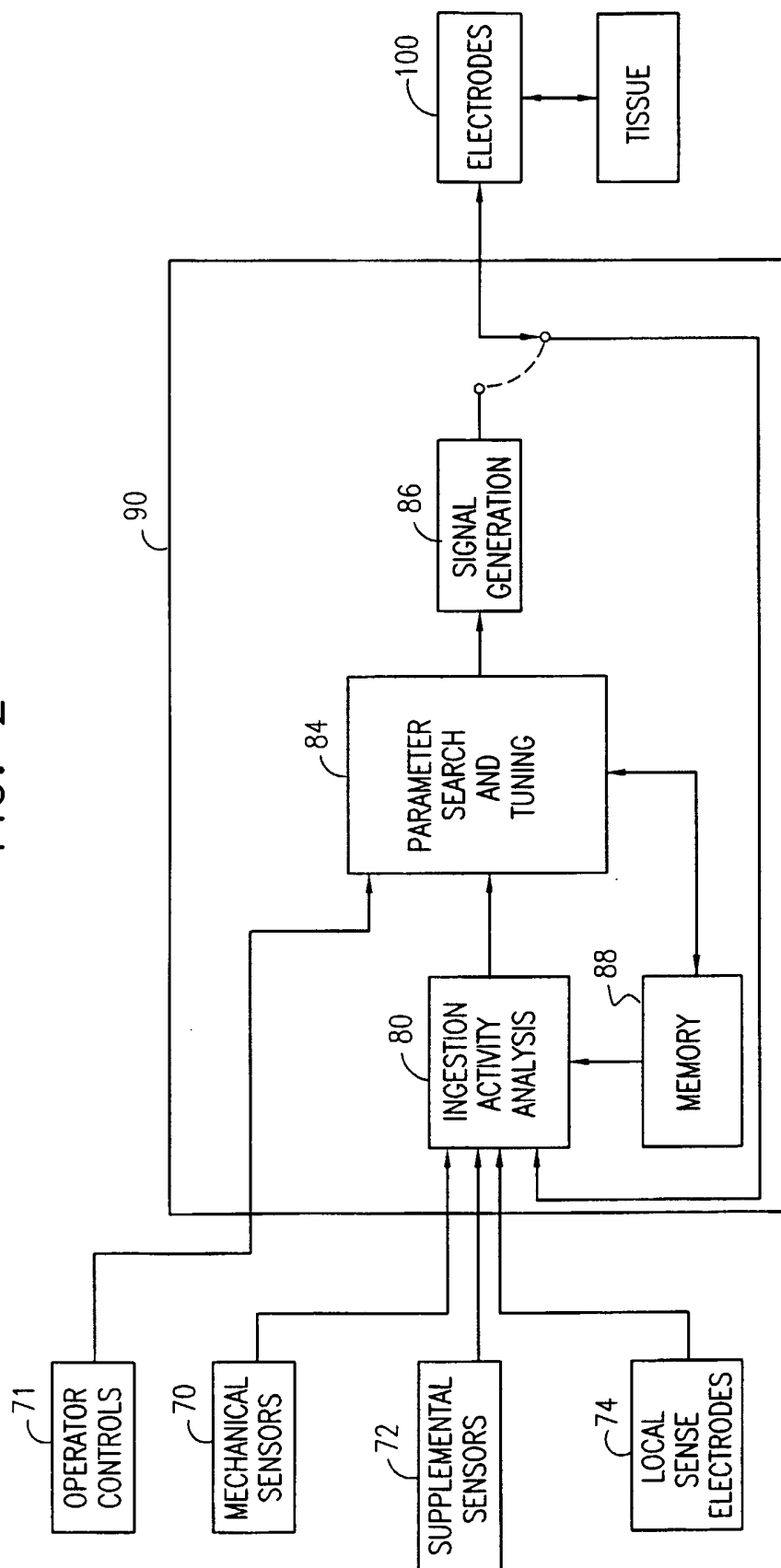


FIG. 3

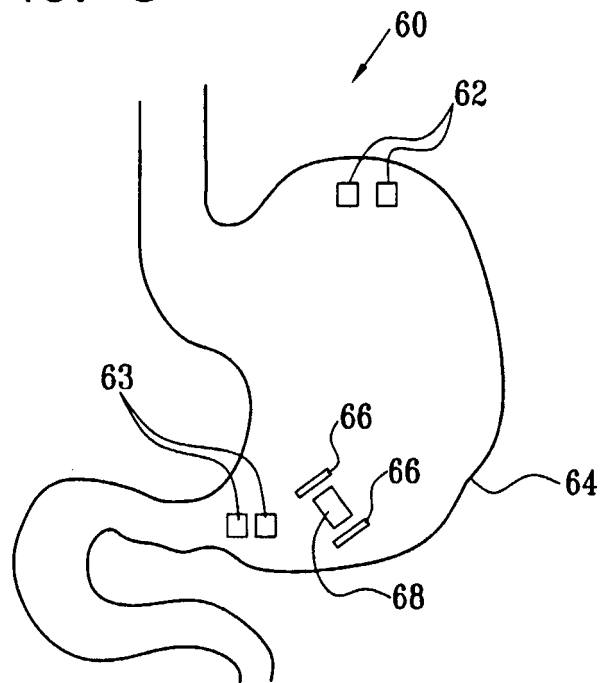


FIG. 4

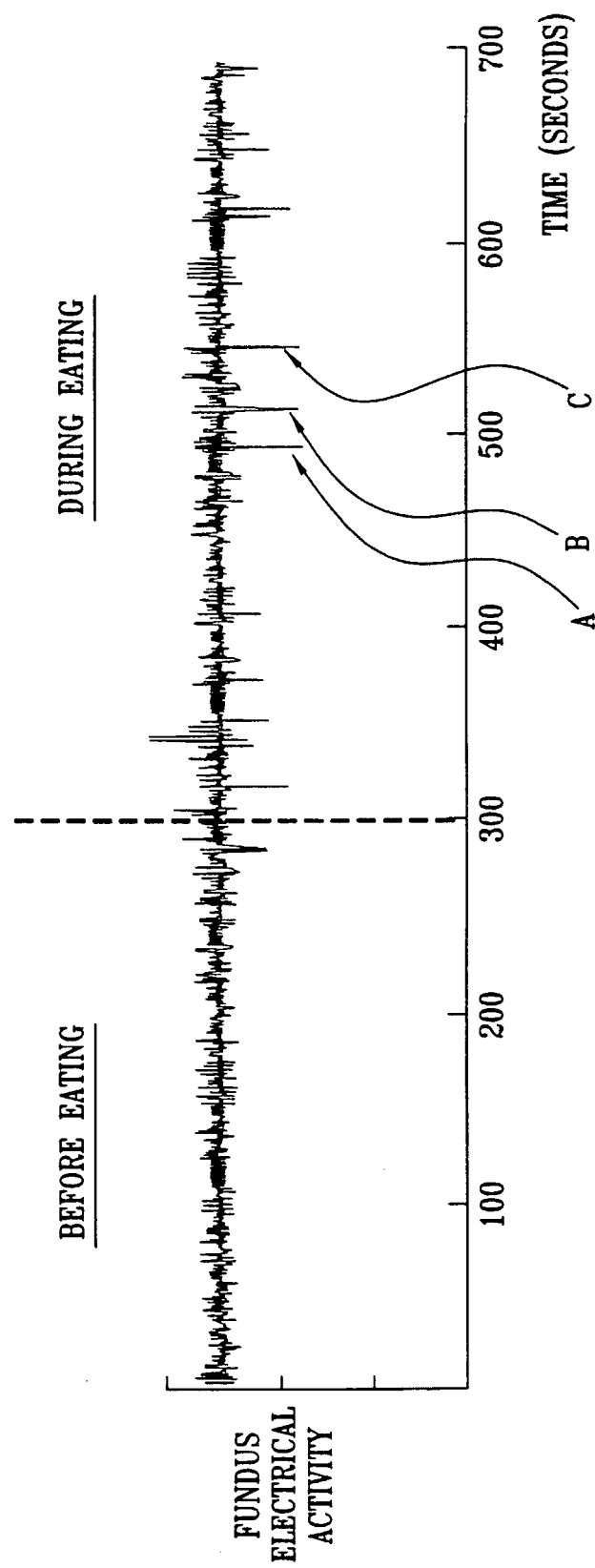


FIG. 5A

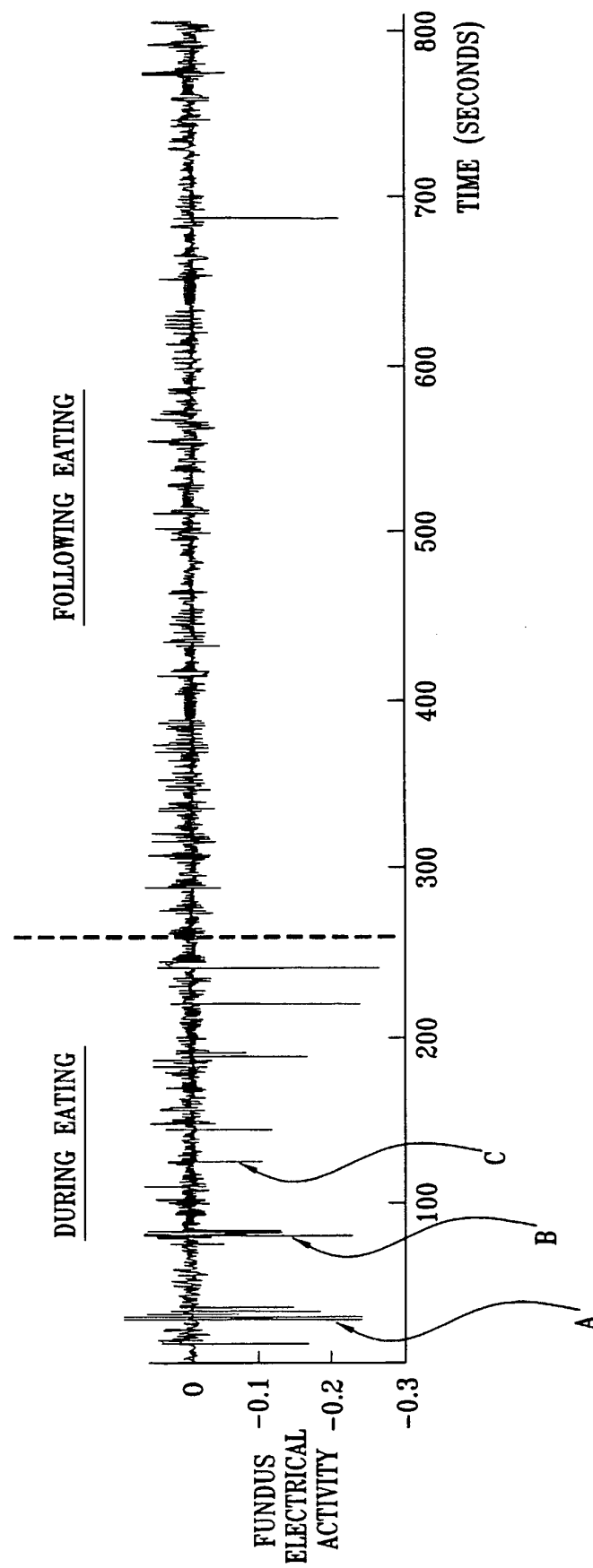


FIG. 5B

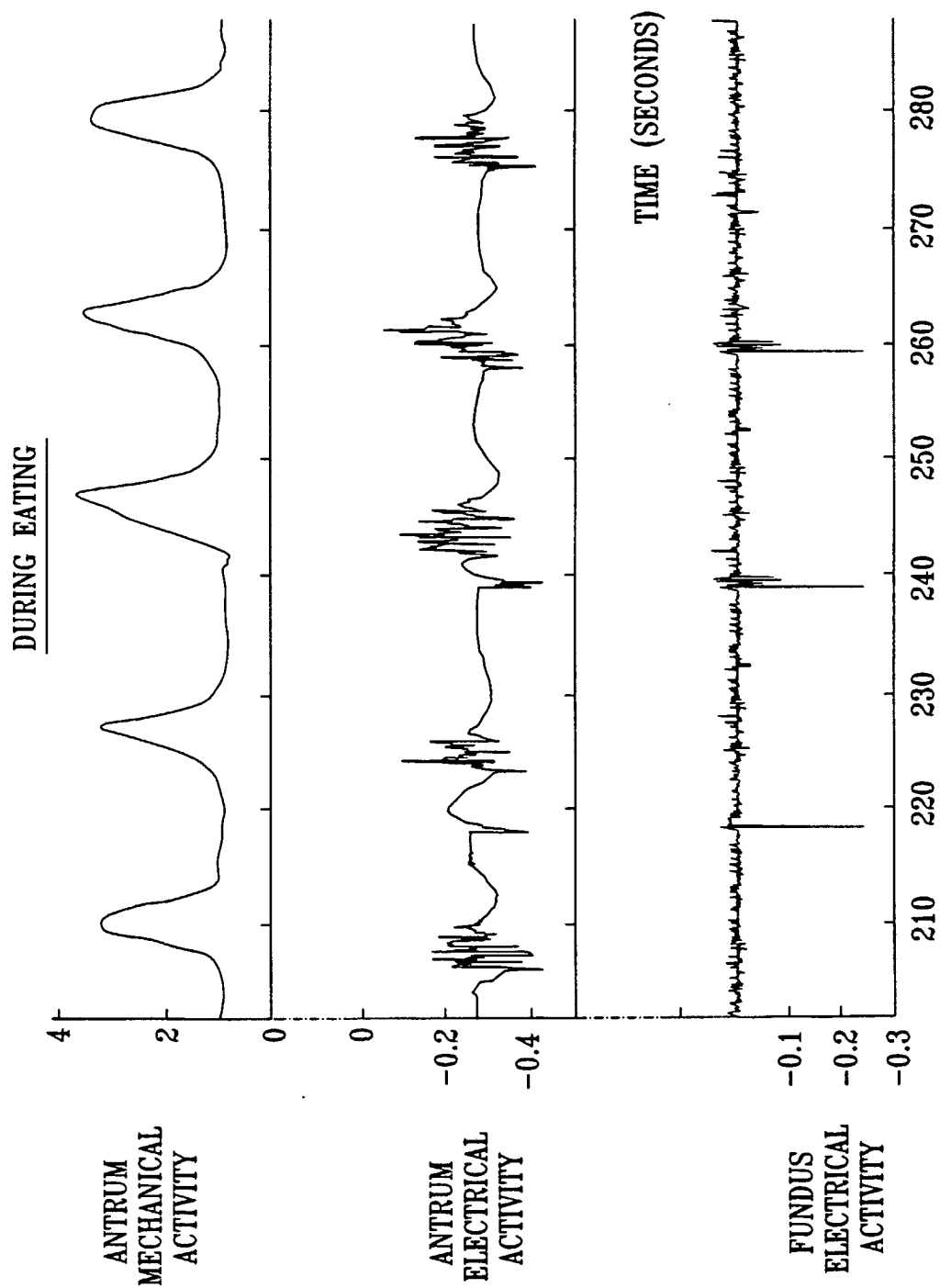


FIG. 6

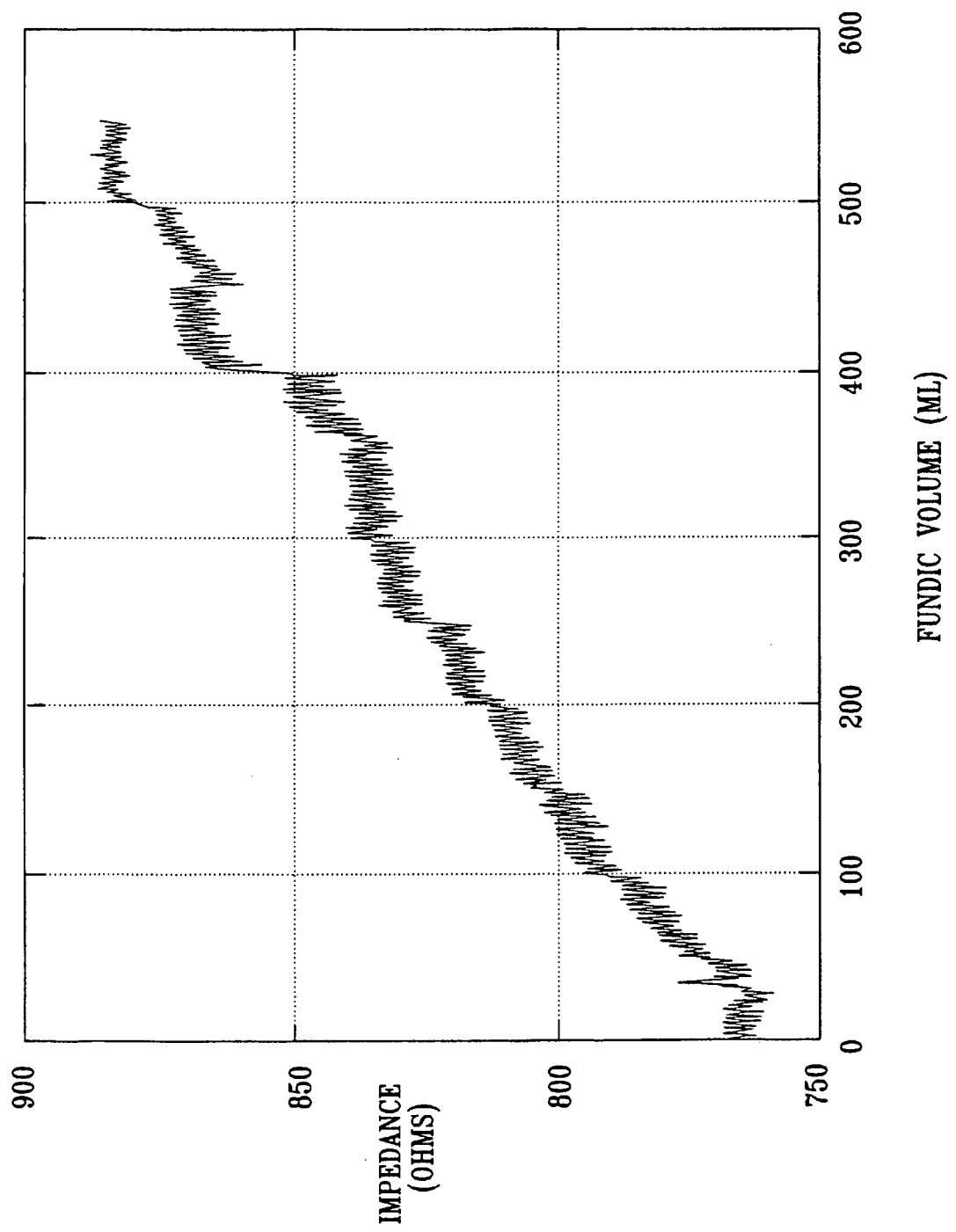


FIG. 7

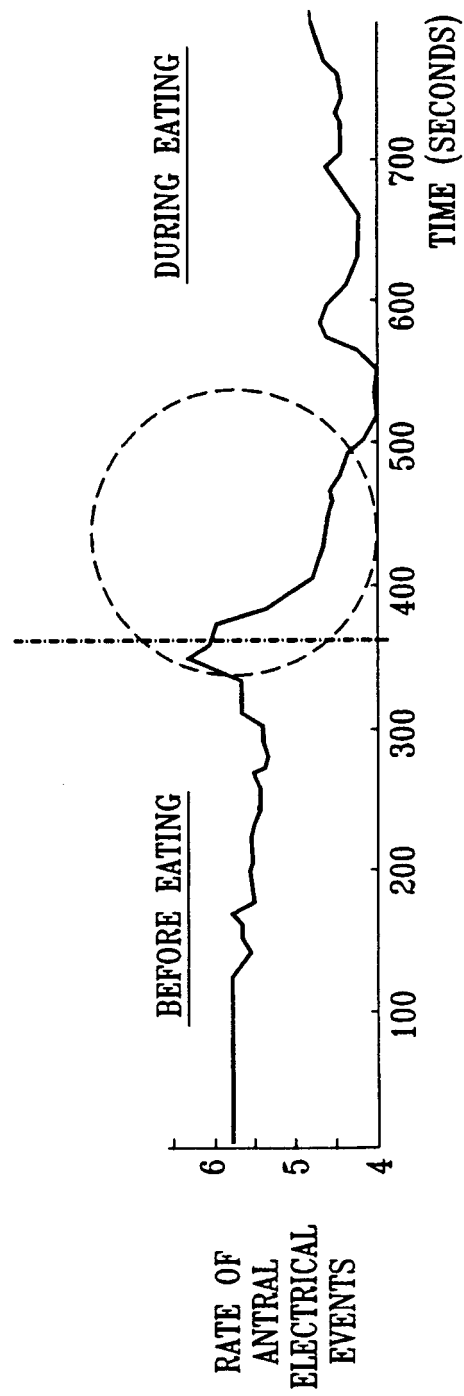


FIG. 8

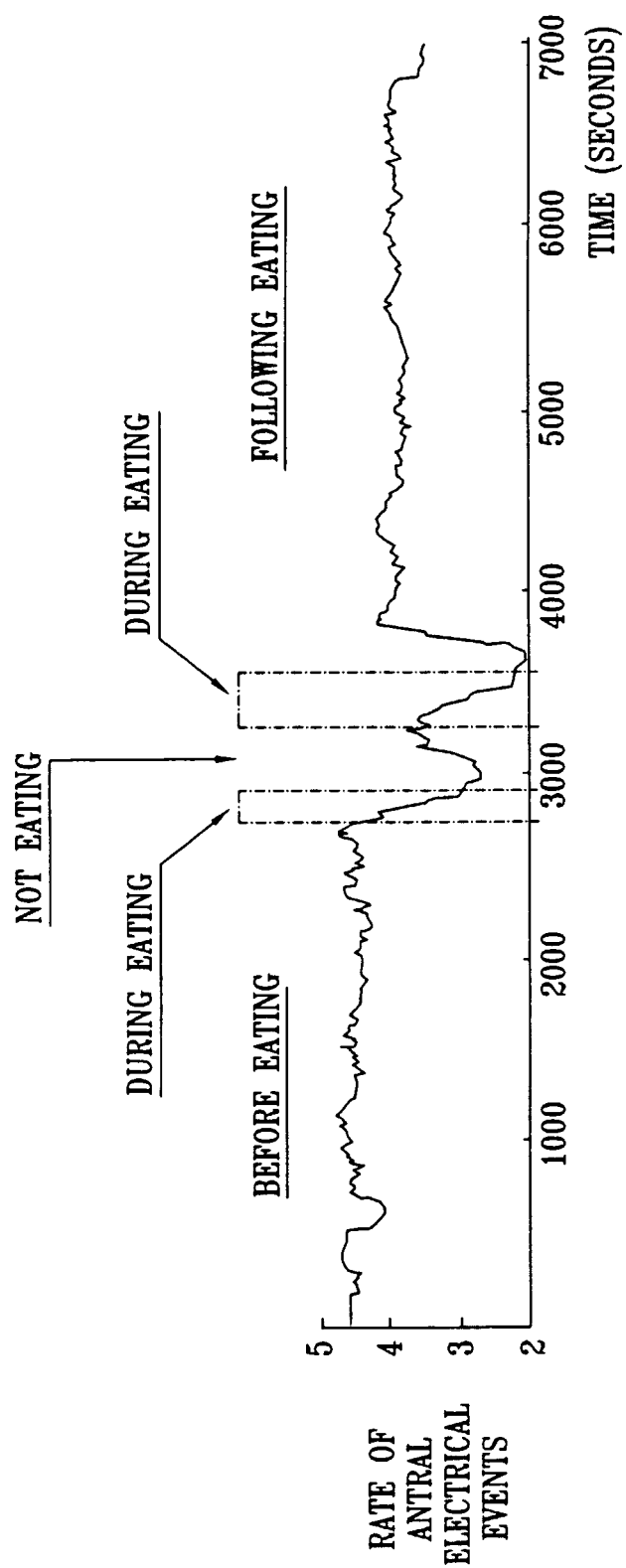


FIG. 9

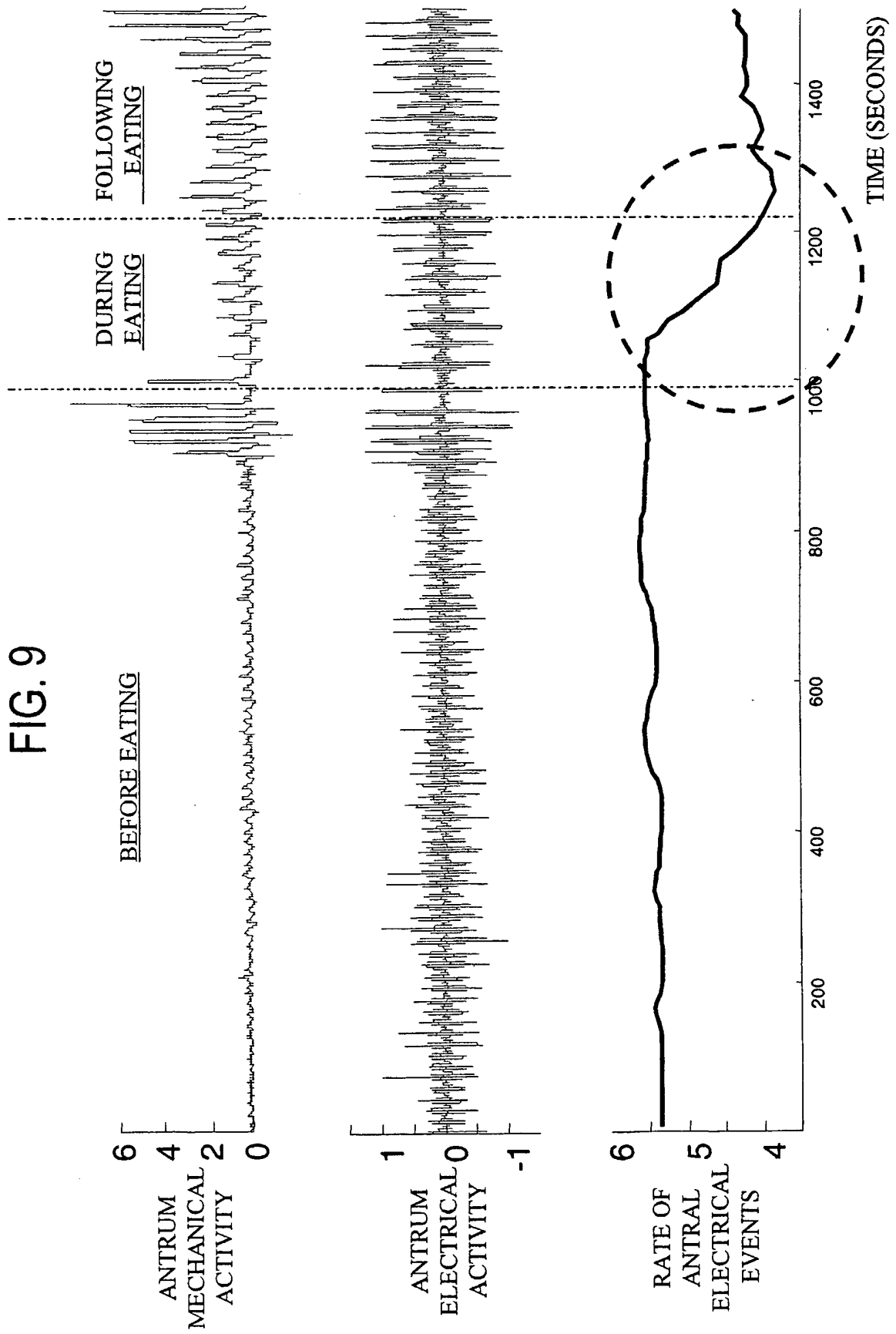
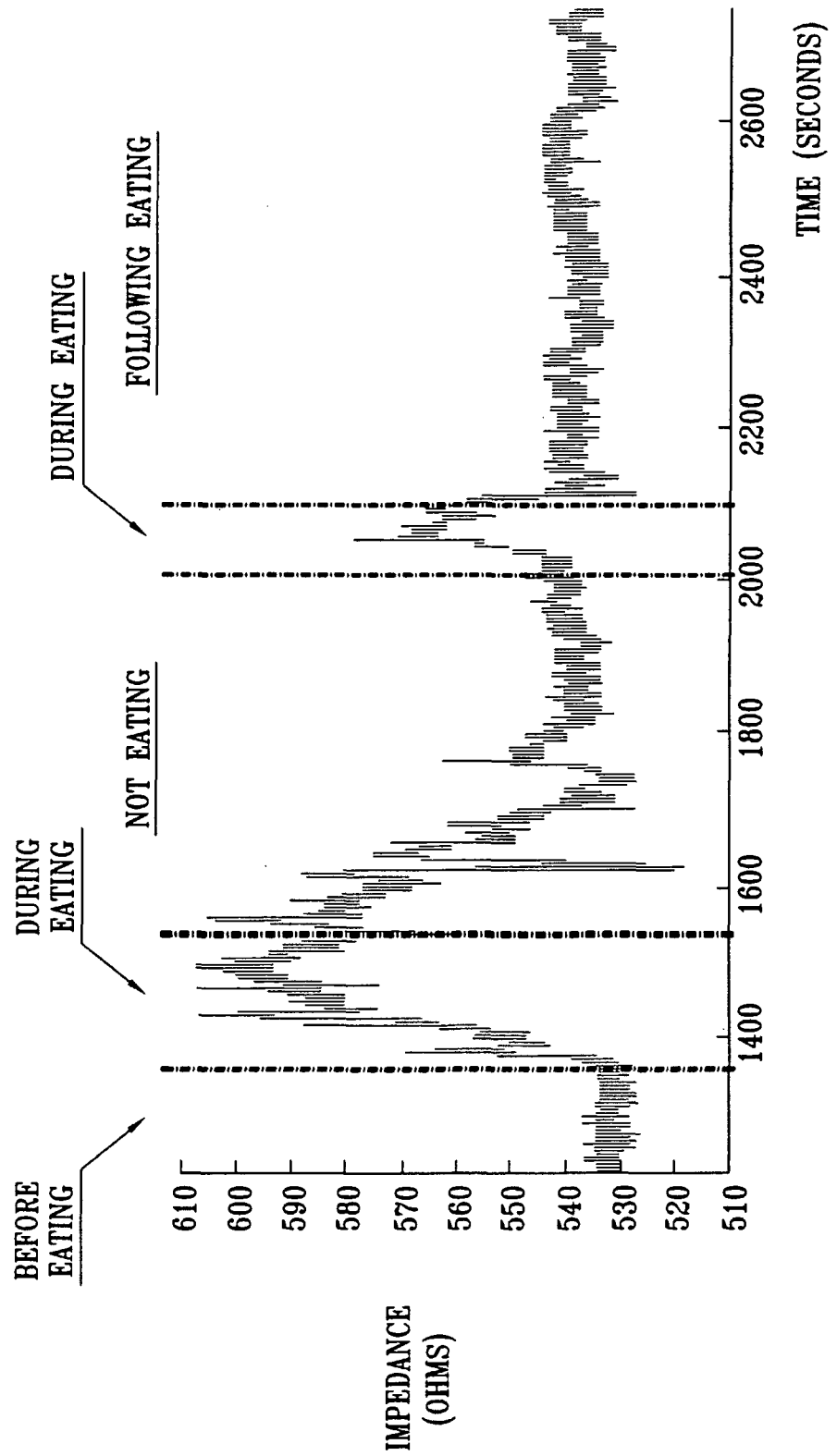


FIG. 10



REFERENCES CITED IN THE DESCRIPTION

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摘要(译)

胃设备 (18) , 包括 : 一组 (a) 一个或多个可植入的窦传感器 (70,74) , 适于连接到受试者的胃窦 (20) 的胃窦部位并产生响应于胃窦特性的窦传感器信号 , 和/或 (b) 一个或多个可植入的基础传感器 (70,74) , 适于连接到胃 (20) 的胃底的胃底部位并产生基底传感器信号响应眼底的属性;一组一个或多个电流施加电极 (100) , 适于耦合到受试者的组织;控制单元 (90) , 适于 : 接收并执行对胃窦和/或胃底传感器信号的分析 , 响应于此确定受试者摄取的食物特征 , 并响应于分析来驱动电流 , 通过一组电流施加电极 (100) 进入组织。